World Radio History

TEST GEAR VOL.2

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Editor: Jan Vernon
Managing Editor: Collyn Rivers
Managing Director: John Fink
Advertising: Sydney 33-4282
Melb. 662-1222

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Sound Level Meter

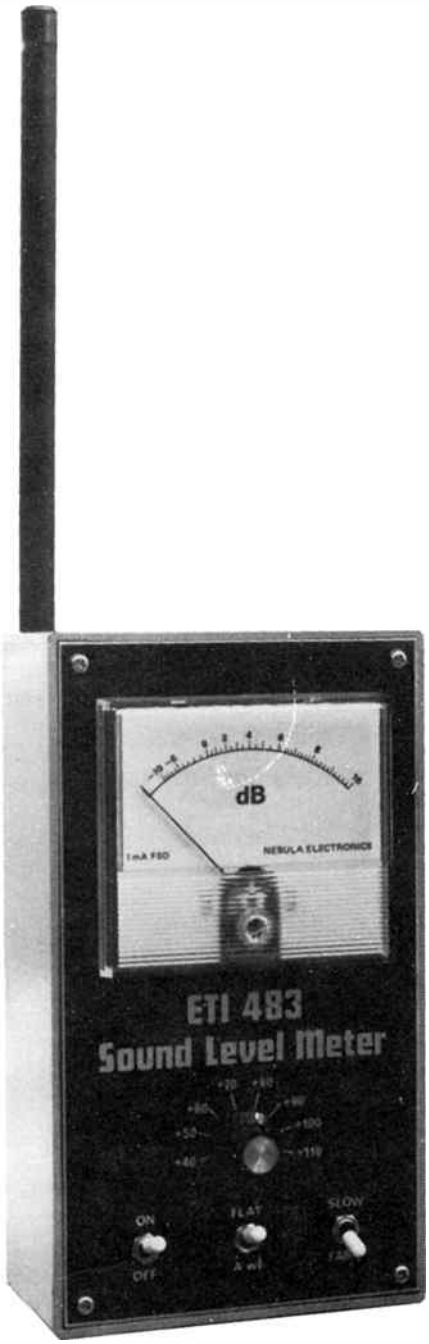
This sound level meter gives accurate results to allow noise levels to be monitored and controlled. An 'A' weight response is provided as well as the 'flat' mode.

THE PUBLIC TODAY is increasingly critical of excessive noise levels. Aircraft like the Concorde, for example, face opposition on grounds of noise levels while jet aircraft of around 1958 were just as noisy but then they were a great advance in science! Public awareness of noise has caused laws to be passed limiting the sound levels which can be produced without prosecution.

However, while it may be good to have a law to say the acoustic output of your party should not exceed 85 dB, how can you tell precisely what the actual level is! If the local constable is called the chances are he will not have a meter and will only be able to give his subjective assessment.

For this reason we have designed this project. It is not a super-duper do-all sound level meter but one which is economical yet gives meaningful results. The microphone used is relatively cheap (about $3.00), but is rugged and has a good frequency response. The microphone used in the B & K sound level meter is delicate and costs a small fortune !

There are many weighting networks used with sound level meters including ones which need a computer to calculate the results. We chose only the two most popular, the "A" weight and flat. The response of the "A" weight filter is given in Fig. 2.



SPECIFICATION – ETI 483

Sound level range	30dB to 120dB
Weighting networks	Flat or 'A' weight
Microphone	Electret
Power supply	9V dc @ 10mA

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Construction

Assemble the PC board according to the overlay in Fig. 4. The rotary switch can be either of the two popular sizes and can be mounted either with tinned copper wires or by drilling large (3mm) holes in the PC board, through which the leads of the switch can be passed and soldered directly to the tracks. Check when assembling that the wiper contact is in the correct position.

Assemble the front panel and leave the leads to the switches and meter long enough to be able to hinge it forward, as the PC board is mounted in the base of the box. The microphone insert is mounted on the end of a length of aluminium tube well away from the box. This is to help prevent reflections from the box affecting the readings. We attached the microphone using a length of heat shrink tubing over the aluminium tubing.

Calibration

This is a little difficult as a known reference is needed or another sound level meter to match it against. Initially however the "flat" attenuator potentiometer must be adjusted. To do this a 1kHz audio tone or sine wave signal across R1 is needed. Select "A" weight and an appropriate range and note the reading. Switch to "flat" and adjust RV1 to give the same reading.

Calibration is performed by RV2 and is adjusted with a known audio signal.

When this unit was originally published, an LM301A was used for IC3. It was subsequently found that some LM301As caused non-linear readings. Replacing the LM301A with a CA3140 cures the non-linearity but on some devices the offset voltage prevents the needle settling on the lowest mark when in a quiet location and on the 110 dB range. If this is only slight, simply turn the meter zero adjust. However if not enough range is available, a trim potentiometer (10 k) connected between pins 1 and 5 on IC3 with the wiper connected to the 0V line will allow adjustment.

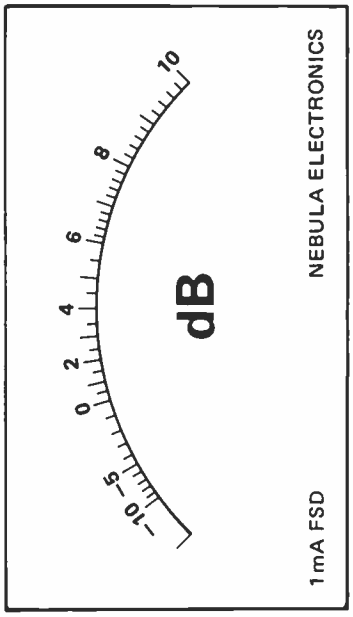


Fig. 1. The meter scale shown full size.

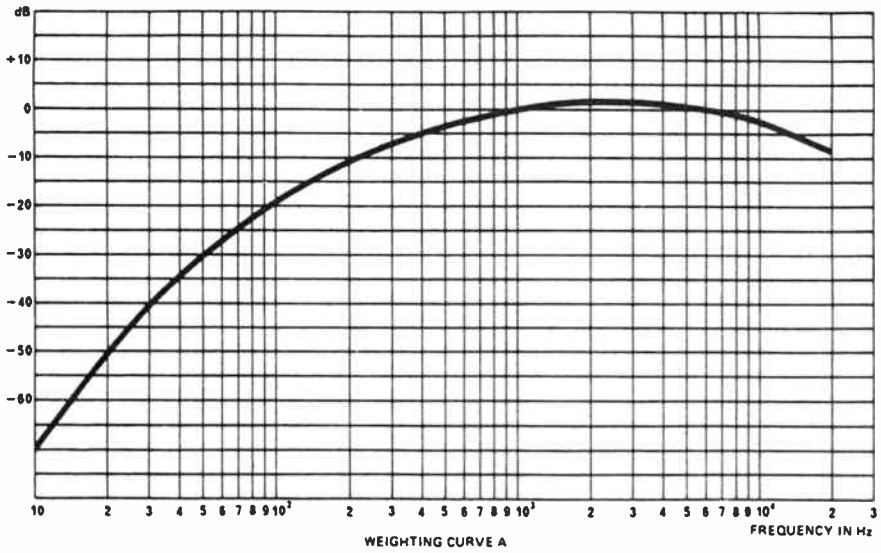
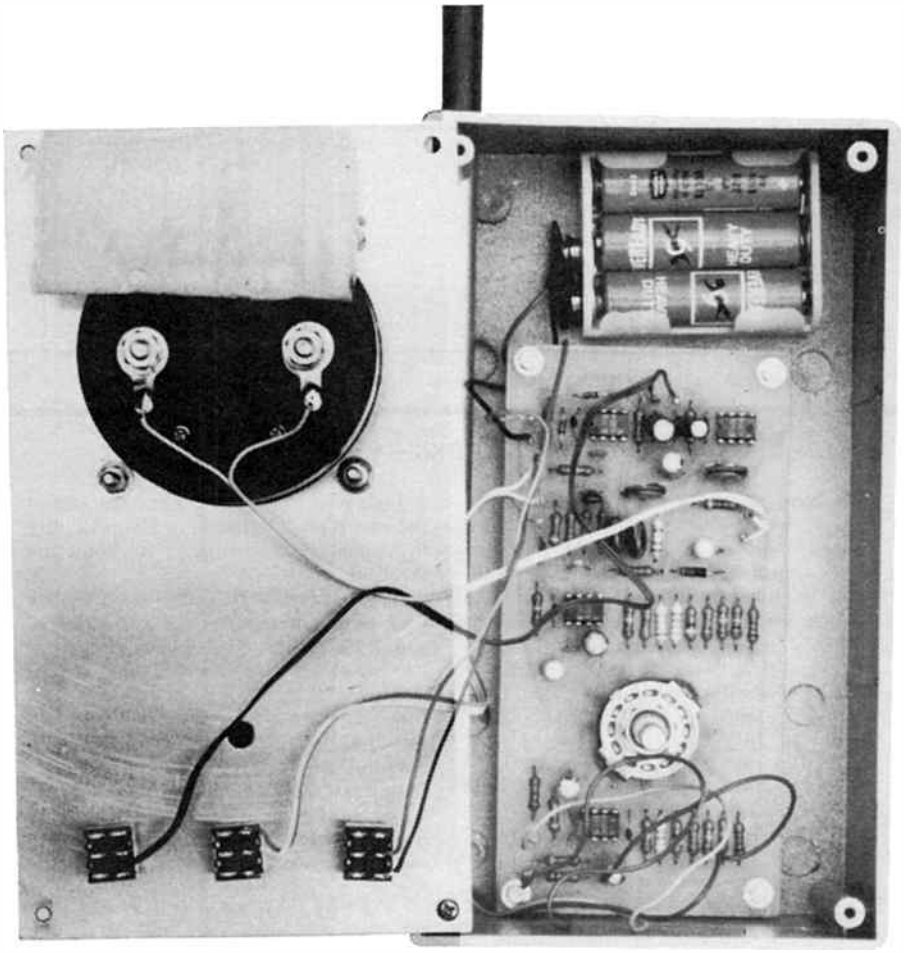


Fig. 2. The response of the 'A' weight filter.



An internal view of the unit.

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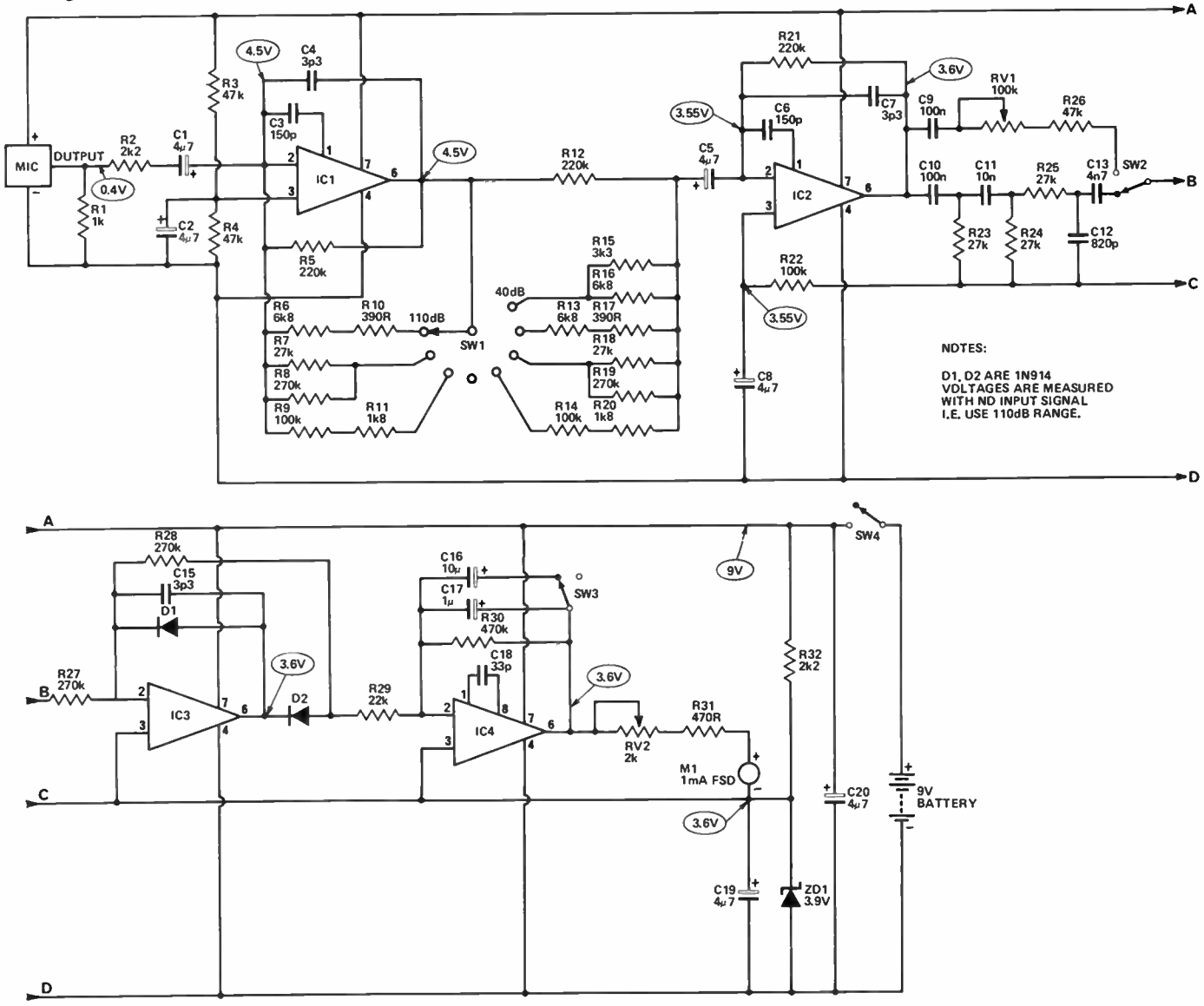

Fig. 3. The circuit diagram of the unit.

HOW IT WORKS – ETI 483

We have used an electret microphone insert which has the necessary FET preamp inside. As its output is a low level, especially in ambients around 40dB it is amplified by IC1 and IC2. The range switch SW1 is used to vary the gain of both ICs as shown below:

Range (dB)	Gain IC1 (dB)	Gain IC2 (dB)	Total Gain (dB)
+40	40	40	80
+50	40	30	70
+60	40	20	60
+70	40	10	50
+80	40	0	40
+90	30	0	30
+100	20	0	20
+110	10	0	10

The use of a switch as shown allows a single pole switch to control the gain of the two ICs while reducing the possibility of instability where gains of 80dB are involved.

The output of IC2 is filtered by the "A" weight network C10-C13, R23-R25 and R27. Switch SW2 selects either this "A" weighted output or the "flat" output via RV1, R25. The potentiometer RV1 is necessary to compensate for the loss of the filter network. Both networks should have the same loss at 1kHz.

IC3 is used to halfwave rectify the signal and IC4 integrates the signal to give the average level. Two values of integration capacitor are used to give the two response speeds.

The bias for the first IC is provided by R3 and R4 while the other three are biased by the voltage across ZD1. The meter is also biased to the zener voltage.

The printed circuit board for this project is reproduced on page 126.

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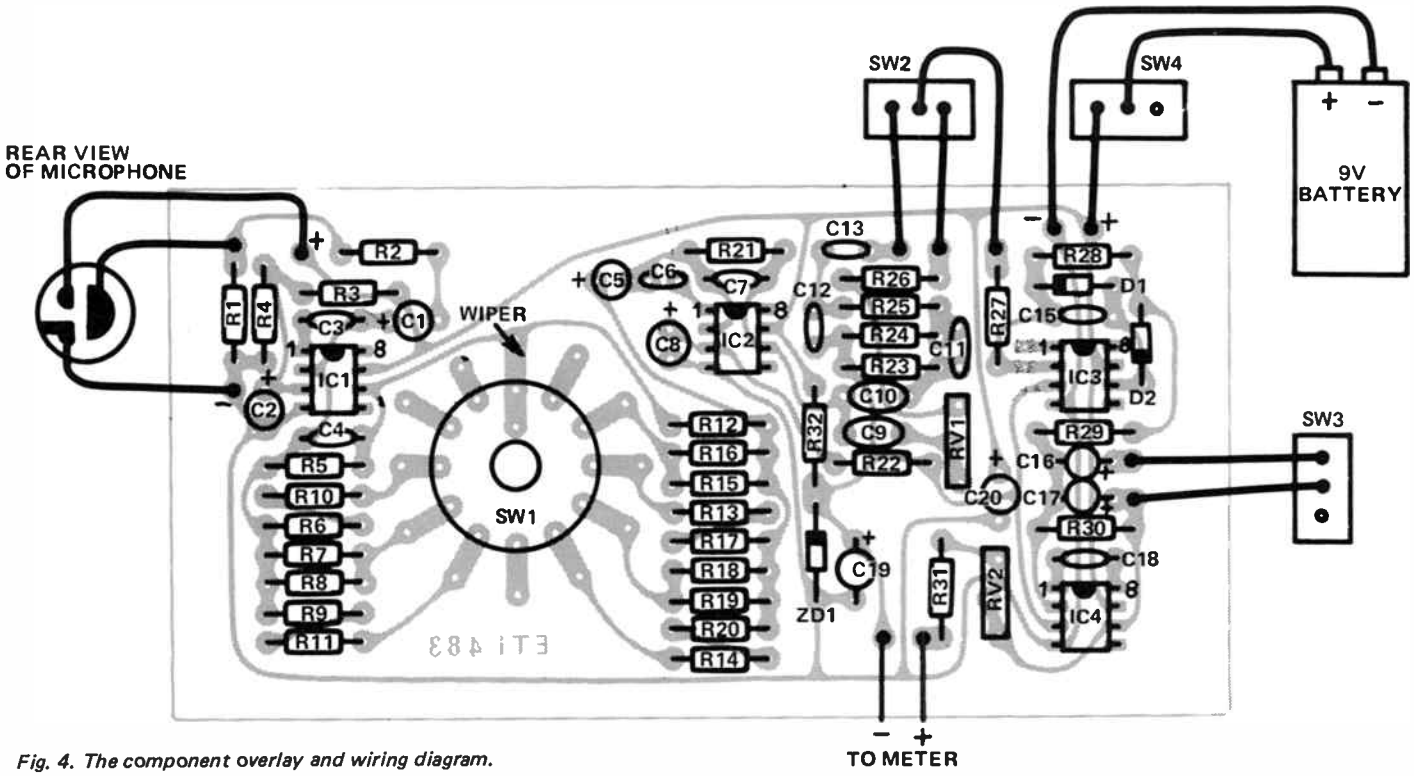


Fig. 4. The component overlay and wiring diagram.

PARTS LIST – ETI 483

Resistors all ½W 5%

R1	1k
R2	2k2
R3,4	47k
R5	220k
R6	6k8
R7	27k
R8	270k
R9	100k
R10	390R
R11	1k8
R12	220k
R13	6k8
R14	100k
R15	3k3
R16	6k8
R17	390R
R18	27k
R19	270k
R20	1k8
R21	220k
R22	100k
R23–R25	27k
R26	47k
R27,28	270k
R29	22k
R30	470k
R31	470R
R32	2k2

Potentiometers

RV1	100k trim
RV2	2k "

Capacitors

C1,2	4µ7 16V electro
C3	150p ceramic
C4	3p3 "
C5	4µ7 16V electro
C6	150p ceramic
C7	3p3 "
C8	4µ7 16V electro
C9,10	100n polyester
C11	10n "
C12	820p ceramic
C13	4n7 polyester
C15	3p3 ceramic
C16	10µ 16V electro
C17	1µ0 16V "
C18	33p ceramic
C19,20	4µ7 16V electro

Semiconductors

IC1,2	LM301A
IC3	CA3140
IC4	LM301A
D1,2	1N914
ZD1	3.9V 300mW

Miscellaneous

PC board ETI 483
Microphone insert for RAPAR ECM1001
SW1 single pole 11 position rotary
SW2–SW4 SPDT toggles
1mA meter
Plastic case
6xAA size battery holder

The Decibel (db)

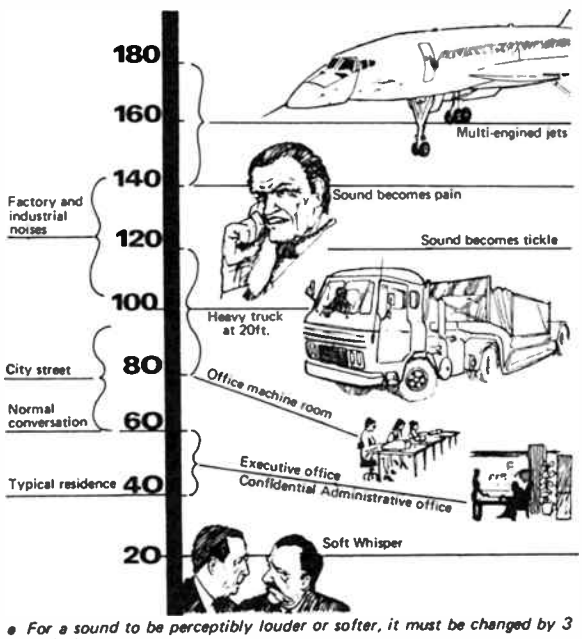
The ear can hear a sound power as low as 10^{-13} watt – this is a pressure of .0002 dynes per cm². The ear drum moves an amount approx. equal to the diameter of a molecule of nitrogen. When sound is uncomfortably loud, the hearer "feels" a tickle, then pain in the ear: a power level of 1 watt. approx.

Engineers take the logarithm of the power ratio and call it the DECIBEL (db).

The db level is given by – $db = 10 \log 10 \frac{Watts}{10^{-13}}$

The sound pressure level is = $20 \log 10 \frac{P(dynes)}{.0002}$

Typical Decibel levels encountered



- *For a sound to be perceptibly louder or softer, it must be changed by 3 decibels.*
- *A noise twice as loud or ½ as loud is a change of 10 decibels.*
- *A reduction in noise of a few decibels in the low noise region (administrative office) is not significant. The same change at high sound levels (office machine room) is significant.*

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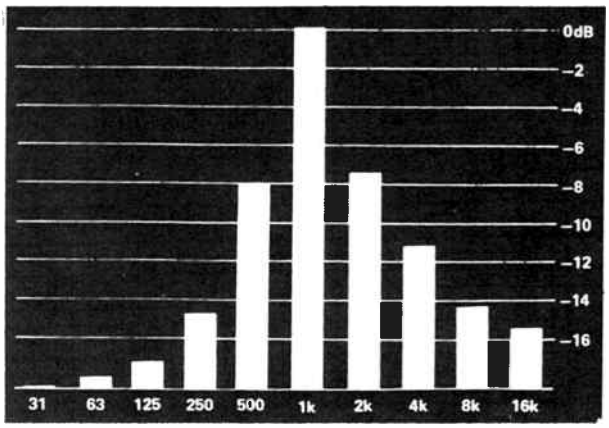
Audio Spectrum Analyser

Equalise systems for room acoustics accurately using this neat piece of 'test' gear.



AUDIO SPECTRUM ANALYSERS can be a valuable tool used in the setting up of a room acoustically with a graphic equalizer such as the ETI 485; to monitor programme material or just as a gimmick to please yourself and friends.

When setting up rooms pink noise is pumped into the room using an amplifier. A microphone is then used to monitor the sound and its output is the input to the analyser. Now by adjusting the graphic equalizer a flat response can (hopefully) be obtained.

SPECIFICATION – ETI 487

No. of bands	10
Frequencies	31, 63, 125, 250, 500, 1k, 2k, 4k, 8k, 16k
Filter characteristics	−12dB, one octave from nominal centre frequency
Display	CRO in XY mode
Input level	50mV – 10V
Input impedance	47k
Pink noise output	200mV
X output	±4 V approx
Y output	0V to 10V

Design Features

Spectrum analysis can be done by two main methods. The first is to have a tuneable filter which is swept across the band of interest. The output of the filter, when displayed on an oscilloscope, will be a frequency/amplitude graph of the input. While this gives a well-formatted and accurate display it is not "real time" in that if an event occurs at one frequency while the filter is sweeping elsewhere it will not be recorded. For this reason this method is used normally where the spectral content is constant and the sweep is only over a small percentage of total frequency (such as the output of a radio transmitter).

For real time analysis the frequency spectrum is broken into bands using bandpass filters and the output of each rectified. The output from these rectifiers can be displayed on a CRO as in this project or by columns of LEDs or similar methods. The number of bands and the dynamic range required determine the filters used. In this project where only about 20dB is required a single LC network is sufficient. Another unit we have built (not for a project) uses a 6 pole high pass filter followed by a 6 pole low pass one. This gives a flat response (∓ 1dB) over ∓ ½ octave and is 36dB down 1 octave away. However, it uses 6 op amps and 2% capacitors and resistors in each filter!

Our LED version of this project starts on page 26.

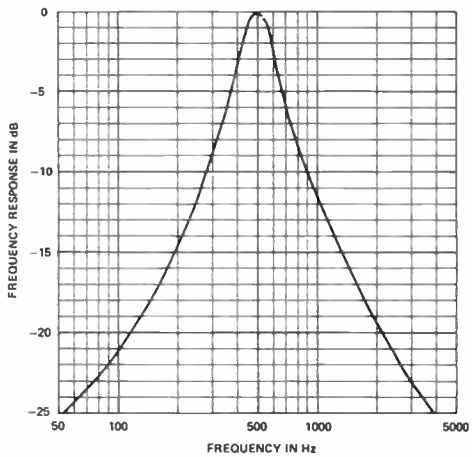


Fig. 1. The frequency response of the 500Hz filter. All other filters follow a similar curve.

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HOW IT WORKS – ETI 487

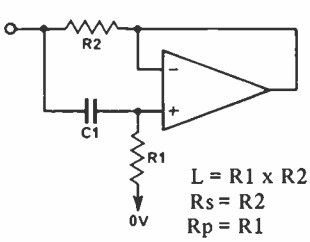
The unit can be broken into eight sections to help the explanation of how it works.

(a) Input amplifier
(b) Ten individual filters and rectifiers.
(c) Ten way analogue switch with decade counter.
(d) Staircase generator controlled by "c". (X output).
(e) Log converter.
(f) Ramp generator and comparator. (Y output)
(g) A pink noise generator.
(h) Power supply.

(a) The input amplifier has an input impedance of 220 k (set by R1) and a gain of 101 ((R3 + R2)/R2). The output of the amplifier drives all ten filters and Q1 and Q2 are used to buffer IC1 to give the drive capability required.

(b) The ten filter-rectifiers are identical except for component values and a bias resistor in the three lowest frequency filters, where tantalum capacitors are used in series. The filter is a parallel LC network which, with a series resistor, gives a band-pass filter.

As large value inductors are expensive we have used an active one using an operational amplifier, two resistors and a capacitor. The value of such a network is as follows:



$L = R1 \times R2 \times C1$ H
$Rs = R2$
$Rp = R1$

The frequency response of the networks is given in fig. 1.

The rectifier is a half wave type where the gain is variable from about 4 to 12. A diode from the output back to pin 2 keeps the op-amp in the linear region on the negative half cycle allowing operation up to the 16kHz of the top filter.

(c) The analogue switches IC23/1 – IC25/2 are controlled by IC22. This is a decade counter with 10 decoded outputs, each of which is high only for one clock period. As the analogue switches need a high to switch them on, only one will be selected at any one time.

(d) The output of the decade counter also controls the staircase generator IC28 with the weighting networks R58 – R72 giving equal steps of about 0.9 volts. Resistor R89 provides a bias current and the output of IC28 starts at about +4 volts and steps down in 0.9V steps to about -4.2 volts when the output switches back to +4 volts. This is used to drive the X input of the CRO. To add some width to the vertical lines, IC29/1 and IC29/2 form an oscillator of about 300 kHz and after filtering by R90 and C69 is coupled into the input of IC28 by R91.

(e) The output of the analogue switch is fed to the diode-resistor network (D21 - D26, R73 - R77) which gives a simple log conversion. This method is simple, needs no adjustments and is adequate for the purpose. As there is some loss in this network IC26 is used to provide a gain of three to recover this loss.

(f) The ramp generator is formed by the constant current (12μA) source and capacitor C71. The capacitor can be discharged by IC25/4 and the current source is controlled by IC24/3. The voltage out of the log converter (IC26) can vary between zero and +10 volts and this is compared to the ramp voltage by IC30. The output of IC30 controls the oscillator formed by IC29/3 and IC29/4. When the ramp voltage exceeds the voltage from IC26 the output of IC30 goes high allowing the oscillator to start. This immediately discharges C71 and switches off the current source which causes the output of IC30 to go low again after only about 2μs. Diode D27 ensures however that the oscillator acts as a monostable giving an output of about 6μs to ensure the capacitor C71 is completely discharged. The output of IC29/4 also clocks IC22 which selects the next input. If the input from IC26 is ever negative and C71 cannot be discharged to less than this voltage, IC29/3 and IC29/4 will oscillate continuously at about 100kHz clocking IC22 until it finds an input higher. This prevents possibility of lockup if the offset voltages of the op-amps all go the wrong way.

(g) White noise is generated by the zener action of Q3 which is reversed biased. It is amplified by Q4 to give 200 mV of white noise on its collector. White noise however has equal energy per unit bandwidth and what we need is pink noise which selects the next input. If the input bandwidth (i.e., equal energy per octave). To convert white to pink we need a filter at 3 db/octave. This is performed by IC27 with the RC networks providing the necessary curve.

(h) The power supply is a simple rectifier type with IC regulators to give stable supply voltages.

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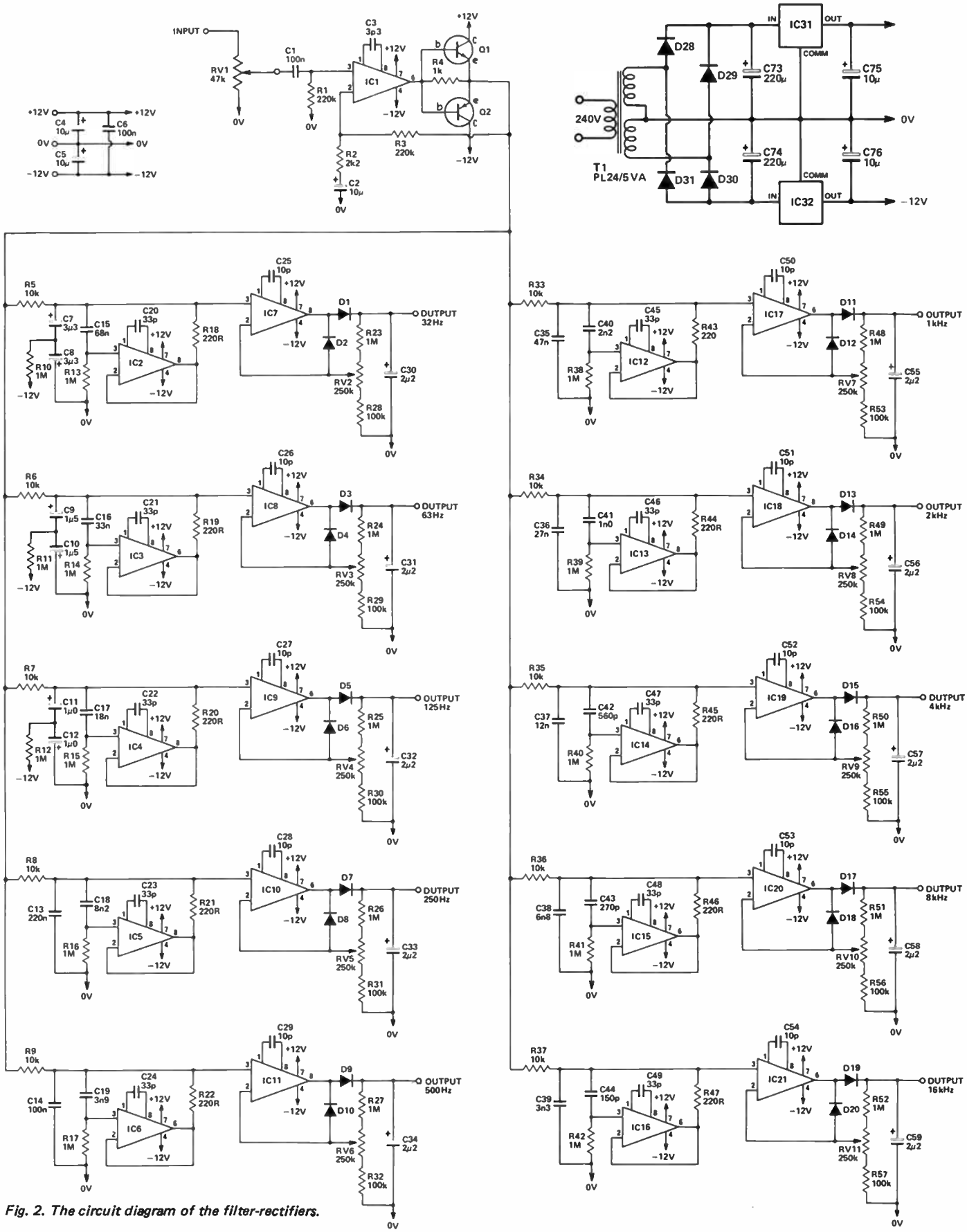

Fig. 2. The circuit diagram of the filter-rectifiers.

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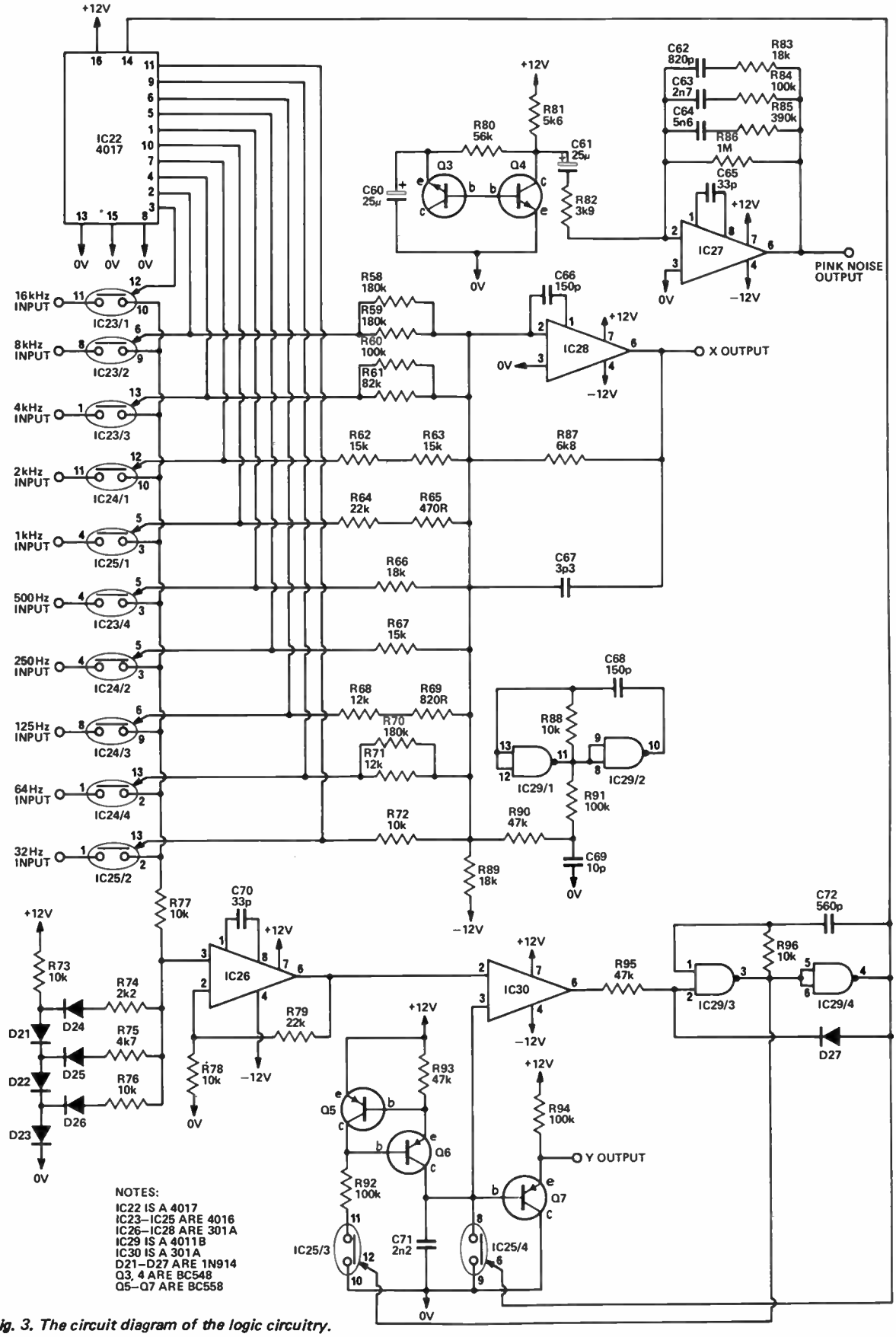

Fig. 3. The circuit diagram of the logic circuitry.

(description continues on page 14)

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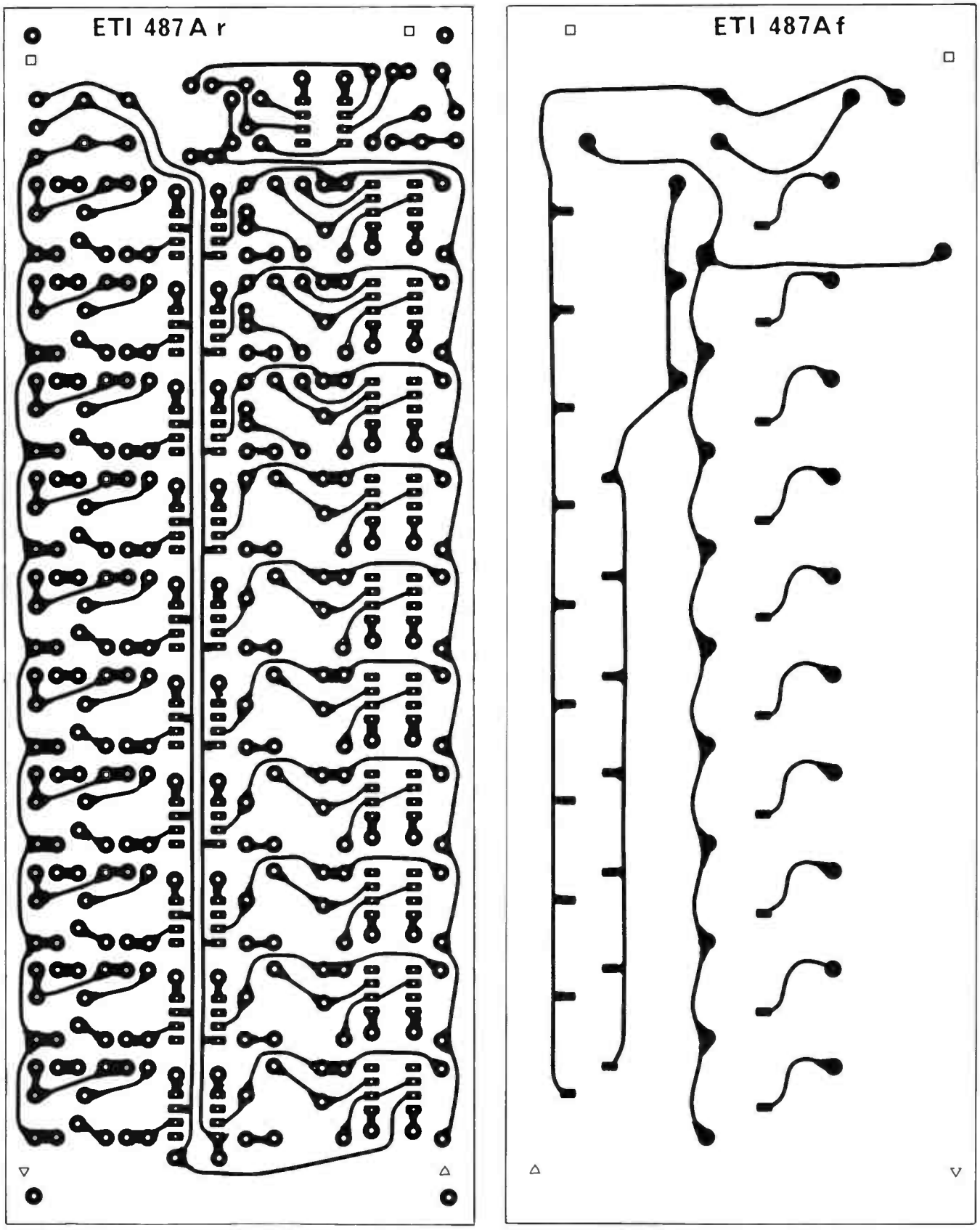

Fig. 4. Both sides of the ETI 487A board shown full size.

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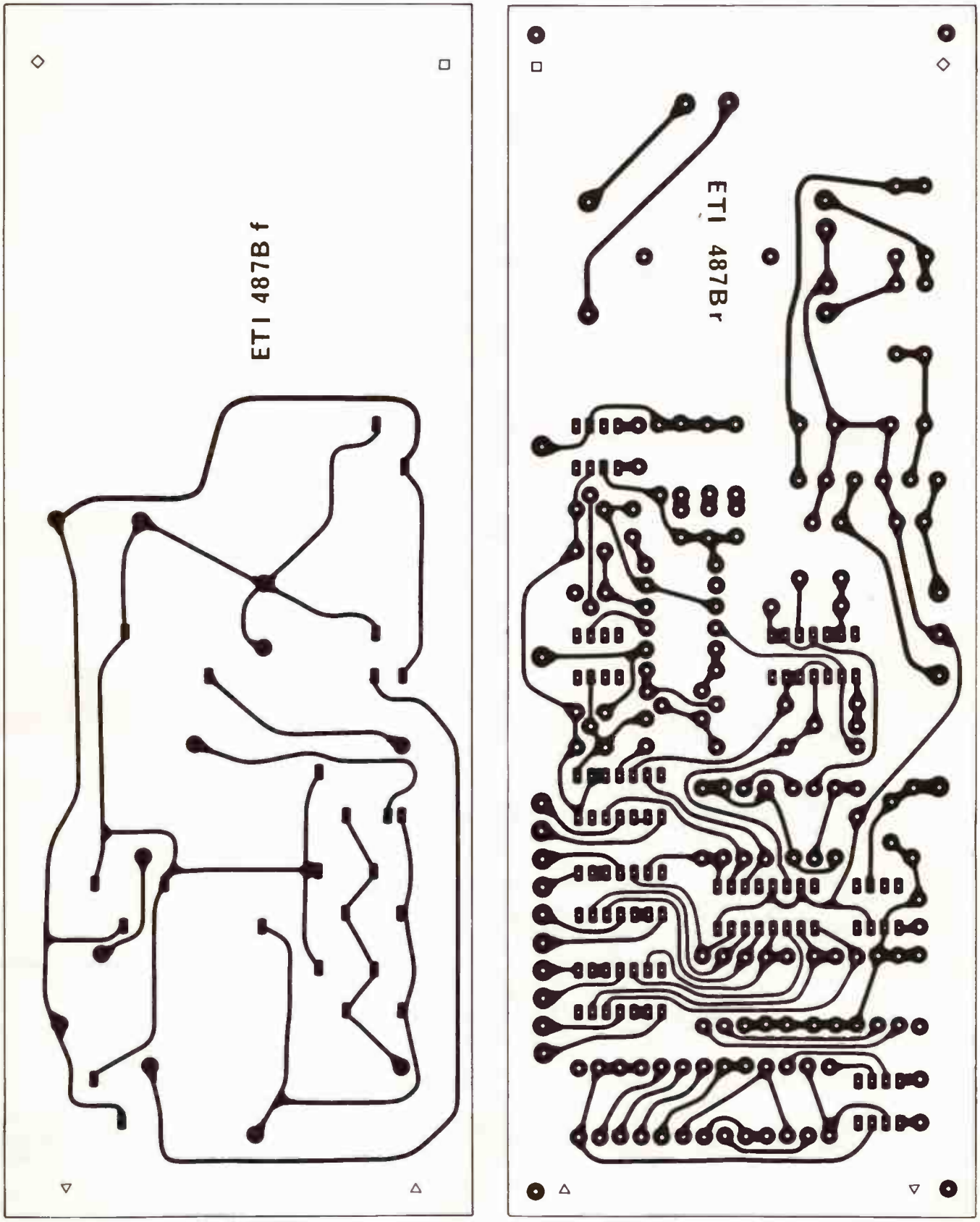

Fig. 9. Both sides of the ETI 487B board shown full size.

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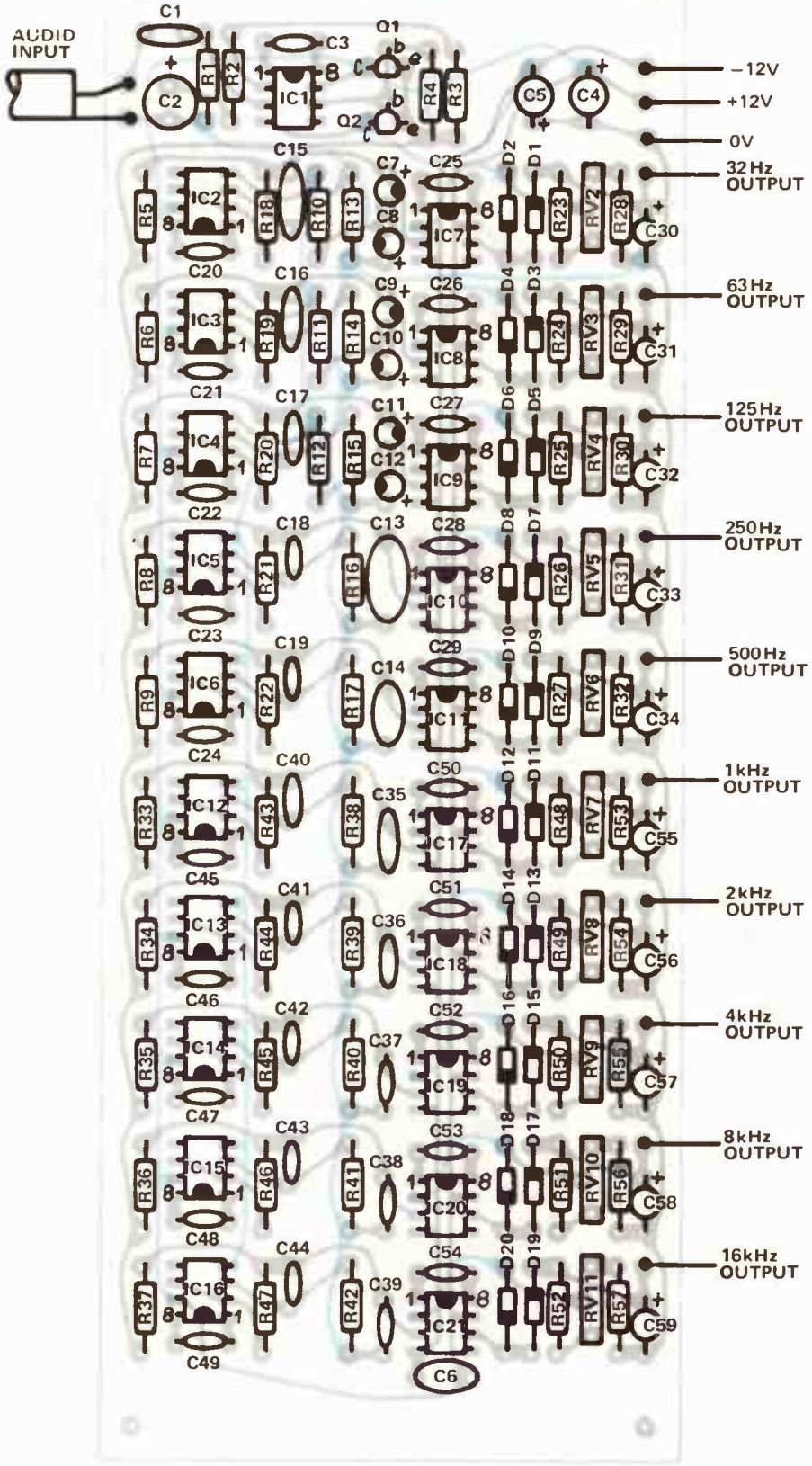

Fig. 5. The component overlay of the filter-rectifier board.

PARTS LIST – ETI 487

Resistors all ¼W 5%

R1	220k
R2	2k2
R3	220k
R4	1k
R5–R9	10k
R10–R17	1M
R18–R22	220R
R23–R27	1M
R28–R32	100k
R33–R37	10k
R38–R42	1M
R43–R47	220R
R48–R52	1M
R53–R57	100k
R58,59	180k
R60	100k
R61	82k
R62,63	15k
R64	22k
R65	470R
R66	18k
R67	15k
R68	12k
R69	820R
R70	180k
R71	12k
R72,73	10k
R74	2k2
R75	4k7
R76–R78	10k
R79	22k
R80	56k
R81	5k6
R82	3k9
R83	18k
R84	100k
R85	390k
R86	1M
R87	6k8
R88	10k
R89	18k
R90	47k
R91,92	100k
R93	47k
R94	100k
R95	47k
R96	10k

Potentiometers

RV1	47k log rotary
RV2–RV11	250k trim

Capacitors

C1	100n polyester
C2	10µ 25V electro
C3	3p3 ceramic
C4,5	10µ 25V electro
C6	100n polyester
C7,8	3µ3 16V tantalum
C9,10	1µ5 16V "
C11,12	1µ0 16V "

Construction

Due to the complexity of the unit it is recommended that PC boards are used. These boards are assembled as per the overlay diagrams. Watch the orientation of all the ICs, diodes, capacitors, etc., when installing them. Note that as the board is not a plated through type that the tracks on the top side of the board must also be soldered to the components. This prevents the use of sockets for the ICs but they are not really worth the cost for low priced ICs

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Capacitors continued

C13 . . . . . 220n polyester
C14 . . . . . 100n "
C15 . . . . . 68n "
C16 . . . . . 33n "
C17 . . . . . 18n "
C18 . . . . . 8n2 "
C19 . . . . . 3n9 "
C20–C24 . . . 33p ceramic
C25–C29 . . . 10p "
C30–C34 . . . 2µ2 25V electro
C35 . . . . . 47n polyester
C36 . . . . . 27n "
C37 . . . . . 12n "
C38 . . . . . 6n8 "
C39 . . . . . 3n3 "
C40 . . . . . 2n2 "
C41 . . . . . 1n0 "
C42 . . . . . 560p ceramic
C43 . . . . . 270p "
C44 . . . . . 150p "
C45–C49 . . . 33p "
C50–C54 . . . 10p "
C55–C59 . . . 2µ2 16V electro
C60,61 . . . . 25µ 16V "
C62 . . . . . 820p ceramic
C63 . . . . . 2n7 polyester
C64 . . . . . 5n6 "
C65 . . . . . 33p ceramic
C66 . . . . . 150p "
C67 . . . . . 3p3 "
C68 . . . . . 150p "
C69 . . . . . 10p "
C70 . . . . . 33p "
C71 . . . . . 2n2 polyester
C72 . . . . . 560p ceramic
C73,74 . . . . 220µ 25V electro
C75,76 . . . . 10µ 25V "

Semiconductors

IC1–IC21 . . . LM301A
IC22 . . . . . 4017 (CMOS)
IC23–IC25 . . 4016 (CMOS)
IC26–IC28 . . LM301A
IC29 . . . . . 4011B (CMOS)
IC30 . . . . . LM301A
IC31 7812
IC32 7912
Q1 . . . . . BC548
Q2 . . . . . BC558
Q3,4 . . . . . BC548
Q5–Q7 . . . . BC558
D1–D27 . . . . 1N914
D28–D31 . . . 1N4001

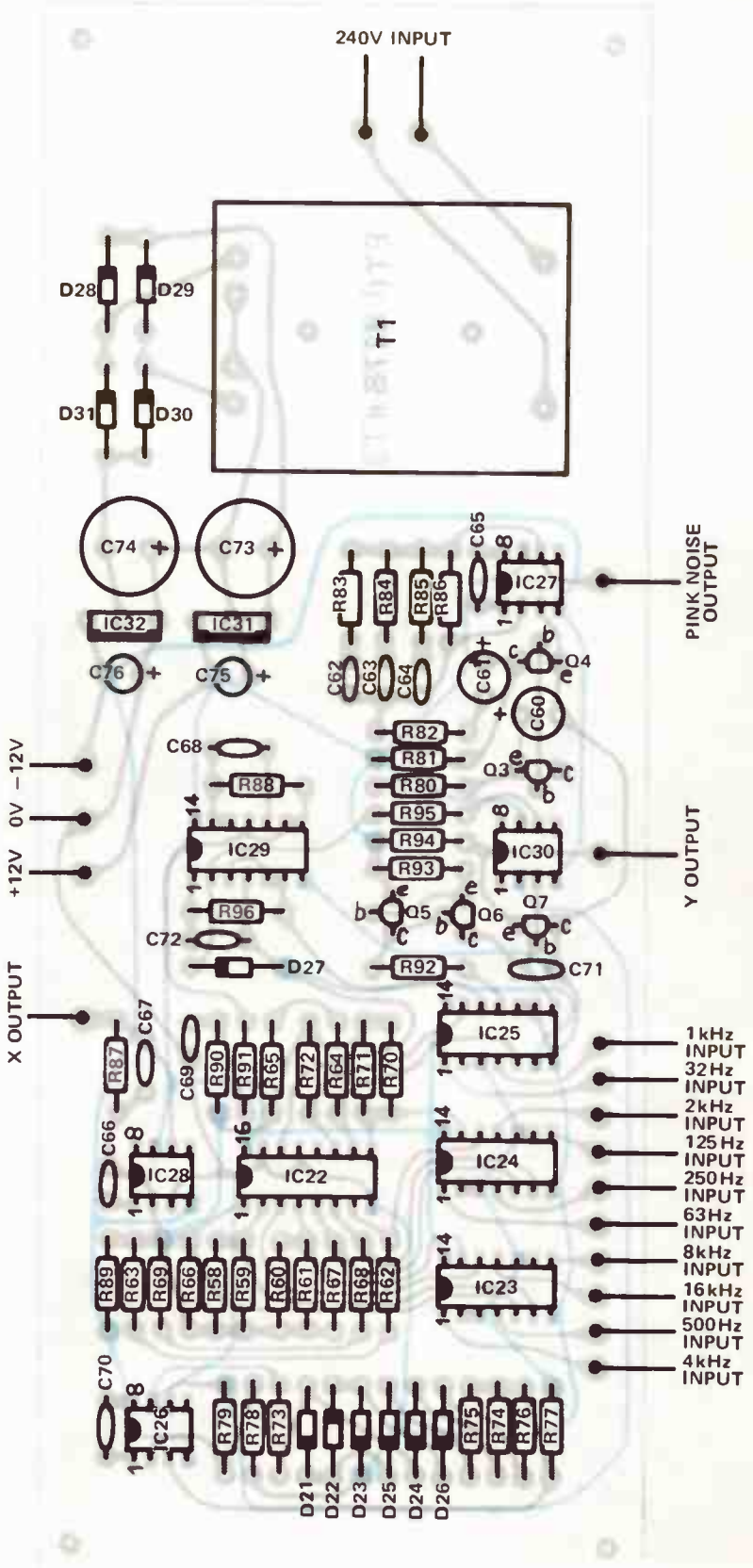
Miscellaneous

PC boards ETI 487A, 487B
Transformer PL24–5VA
Case to suit
3 core flex and plug
240V power switch
Input / output terminals to suit

as used.

With the board 487A be very careful as there is 240V on the board. It is recommended that the wires be terminated directly to the board, without PC board pins, and that the 240V tracks on the underside of the board be coated with epoxy to prevent contact.

We mounted the unit into a home-made box as we did not have a commercial one on hand to suit.



Erratum: Capacitor C75 is shown positioned incorrectly. It should be turned through 180 . A link must also be made between the collector of Q2 and the end of R10 where the −12V track begins on the underside on the board.

World Radio History

Project 487

Alignment

This can be done using the pink noise generator or preferably with a sine wave oscillator.

Connect the unit to the oscilloscope switched into the X Y mode. With the unit switched on and a signal connected, adjust the X gain and shift to obtain a series of ten vertical bars across the screen. Increase the input signal until the columns will not get any higher. Adjust the Y gain and shift until the column is the height of the screen. Note that the scope should be dc coupled.

Now by sweeping the oscillator frequency it will be found that each column will come up in sequence. Adjust the frequency to peak the 16 kHz column. Now adjust RV11 to about 75% of its travel (wiper towards RV10) and then adjust the overall sensitivity control to give a column height of about 80%.

Now using the same amplitude adjust the signal generator frequency until the 8kHz column peaks and adjust RV10 to give the same height. Each of the filters should be adjusted in the same way. Note that due to component variations the actual peak of a filter may not exactly coincide with its nominal frequency. Also the 16kHz filter has the greatest loss which is the reason for starting with it near its maximum gain.

By taking the pink noise output to the input each column should be approximately the same height. Due to the nature of noise the top of the columns will jump up and down a little and this should be averaged out by the eye.

If an oscillator is not available the noise generator can be used and the potentiometers adjusted to give an even response. Also, if desired, a vertical dB scale can be made.

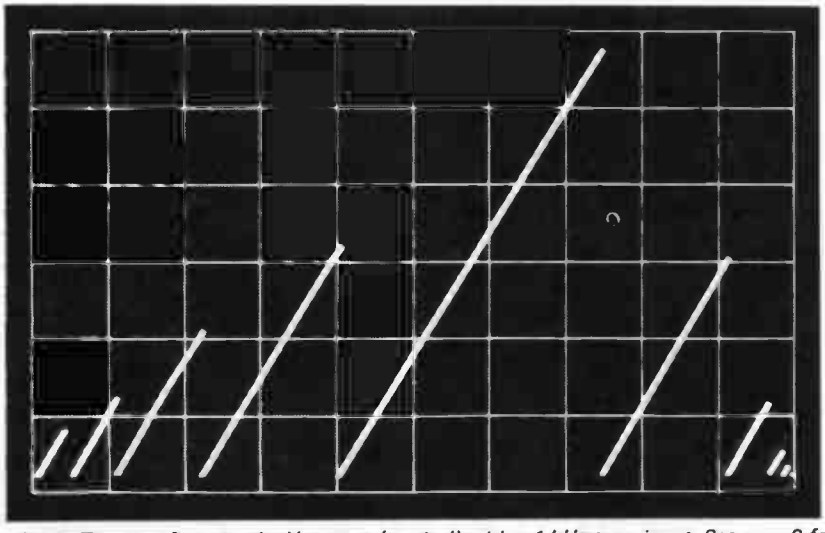


Fig. 7. The waveform on the Y output (vertical) with a 1 kHz tone input. See page 8 for the X-Y display. Note that the time between cycles varies with the height.

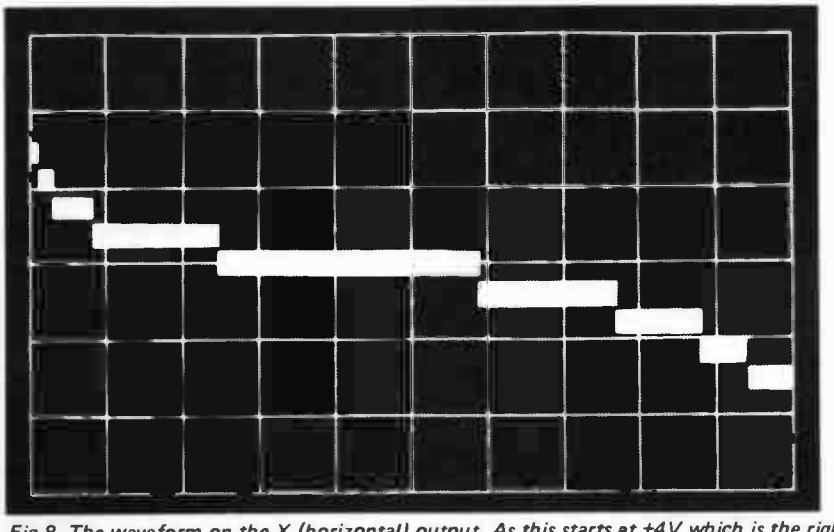
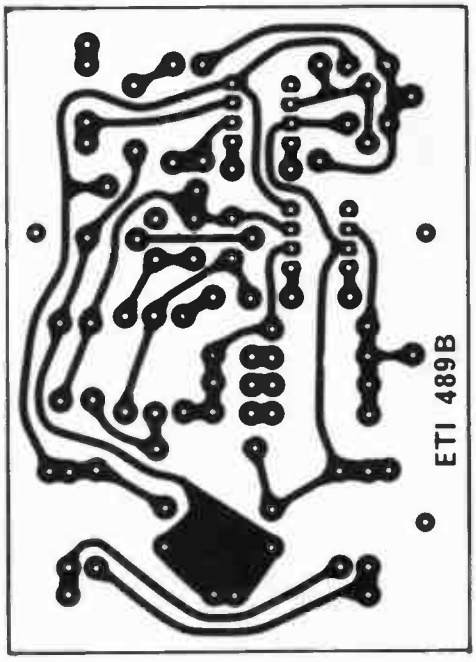
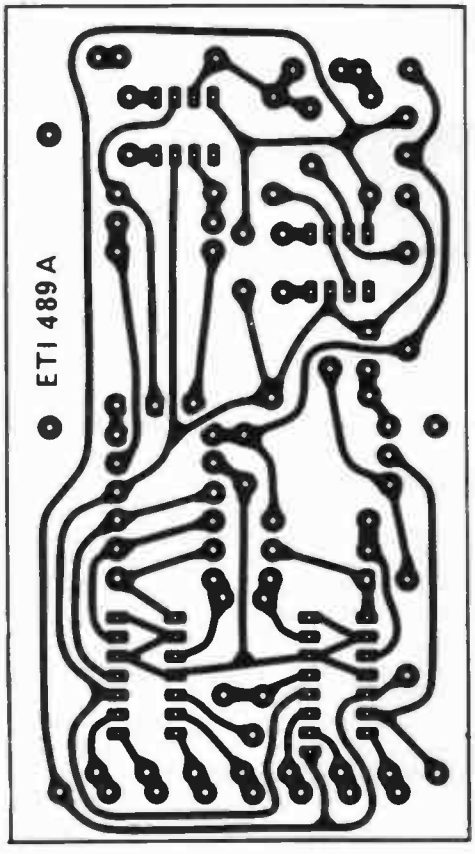


Fig.8. The waveform on the X (horizontal) output. As this starts at +4V which is the right hand side of the screen, the 16 kHz output is sampled first. Note that the time between steps corresponds to that in fig. 7.

AUDIO SPECTRUM ANALYSER 2
(see page 26)
PC Boards 489A & B.





World Radio History

AUDIO OSCILLATOR

Audio oscillator utilises new design in frequency meters, giving good accuracy and fast reading rates.

THE AUDIO OSCILLATOR is an almost essential piece of test equipment in any test lab be it professional or only the home workshop. Only the multimeter would rate more highly. We first published a simple sine-square oscillator way back in 1971 and this design is still very popular and selling well. We decided however to bring the design up to date adding a few improvements, and present it again.

Design Features

This oscillator started out as a redesign, mainly mechanical, of the earlier design. It then started to evolve as a voltage controlled sweep oscillator but when it became too complex we reverted to a simple Wein bridge oscillator.

One major problem with all home made oscillators is that of scaling the frequency dial. This is not just a problem of positioning the knob but since normally available potentiometers have a tolerance of +/- 20%, the scale length will also vary. In commercial units the use of an expensive wire wound potentiometer solves most of the problems giving reasonably accurate scaling.

We then decided to build in a frequency meter, basing it on the ETI 533 display module. However the high power consumption (we wanted to allow battery operation) and the poor resolution, especially at low frequency, prompted the design of a completely new frequency meter.

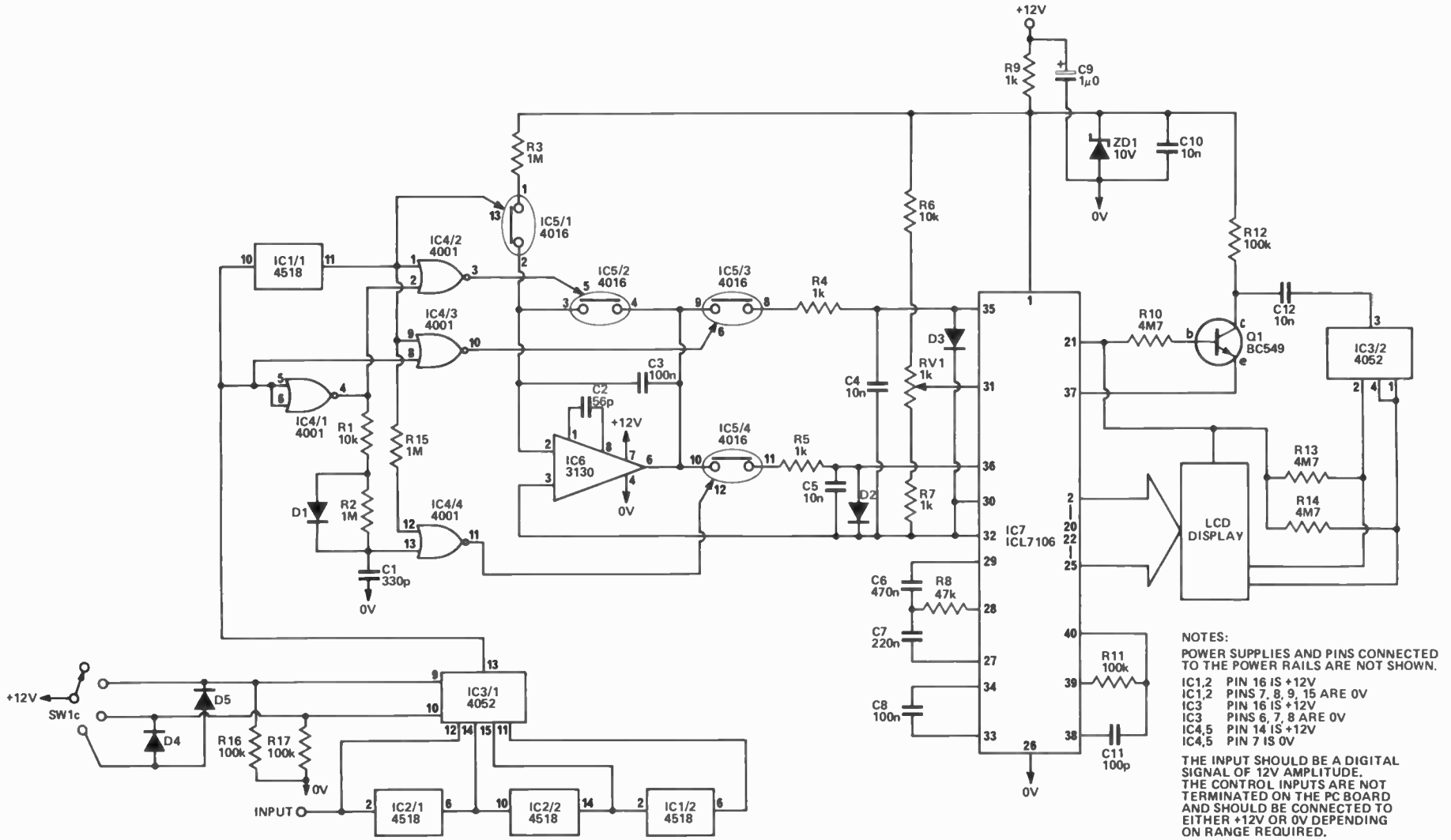
This uses what is literally an analogue computer to convert a period measurement into frequency with some digital electronics controlling it and displaying the results. We based this on the Intersil ICL 7106 module which, due to its liquid

Continued on page 20.

Front view of the audio oscillator. Note that this is an early prototype and the 3V range has been deleted.

World Radio History

AUDIO OSCILLATOR



NOTES:

POWER SUPPLIES AND PINS CONNECTED TO THE POWER RAILS ARE NOT SHOWN.

IC1,2 PIN 16 IS +12V
IC1,2 PINS 7, 8, 9, 15 ARE 0V
IC3 PIN 16 IS +12V
IC3 PINS 6, 7, 8 ARE 0V
IC4,5 PIN 14 IS +12V
IC4,5 PIN 7 IS 0V

THE INPUT SHOULD BE A DIGITAL SIGNAL OF 12V AMPLITUDE. THE CONTROL INPUTS ARE NOT TERMINATED ON THE PC BOARD AND SHOULD BE CONNECTED TO EITHER +12V OR 0V DEPENDING ON RANGE REQUIRED.

Fig. 1. The circuit diagram of the frequency meter section.

World Radio History

HOW IT WORKS - ETI 137

Oscillator

The oscillator is the conventional Wein bridge type with a differenial amplifier made up by Q1-Q5. Gain stabilization is done by the thermistor TH1. This type of circuit oscillates at the frequency where the impedance of the capacitors equals the resistors in the Wein bridge arms. With this feedback network the attenuation does not vary greatly like that of a twin tee but the phase shift does. The result is a sine wave oscillator with low distortion.

For frequency variation a two gang potentiometer is used to give a 20/1 continuous variation with switched capacitors giving four ranges each a decade apart.

The sine wave output is turned into a square wave by IC1 with the amplitude stabilized by D3-D6.

Frequency Meter

This section works by generating a voltage proportional to the period of one cycle and using this as the reference voltage for the Intersil voltmeter IC with a fixed voltage on the normal input. This gives the inverse function of normal operation and the display therefore is frequency.

To generate the reference voltage we use an integrator (IC6) which is controlled by IC5. Operation is as follows. Initially C3 is discharged and for one cycle of the input signal IC5/1 turns on. As the module provides a stable voltage between pin 1 and pin 32 of about 2.8V the output of IC6 will fall linearly with time and as IC5/1 is on for exactly one cycle the voltage change will be proportional to that period.

After IC5/1 turns off the output of IC6 will stay fixed. IC5/3 is then turned on and C4 will charge to that voltage. After half a cycle IC5/3 will turn off leaving C4 at that voltage and IC5/2 will turn on. This discharges C3 to zero volts. After a short delay to allow C3 to discharge IC5/4 is turned on transferring that voltage level onto C5. After a total of two cycles the process recommences. The voltage difference between the two capacitors is therefore the voltage *change*, (proportional to frequency) thus eliminating any offset errors in IC6. The pulses which control IC5 are derived from IC1/1 and IC4.

A reference voltage less than half the input voltage will result in the ICL7106 counting past 2000 (over ranging). The two inputs must also lie within the supply rails (less 1.5V). This limits the range of the instrument from 5 Hz to 200 Hz. For the higher frequency ranges, three decade dividers are provided and the necessary output selected by IC3. The correct decimal point is also selected by the other half of this IC.

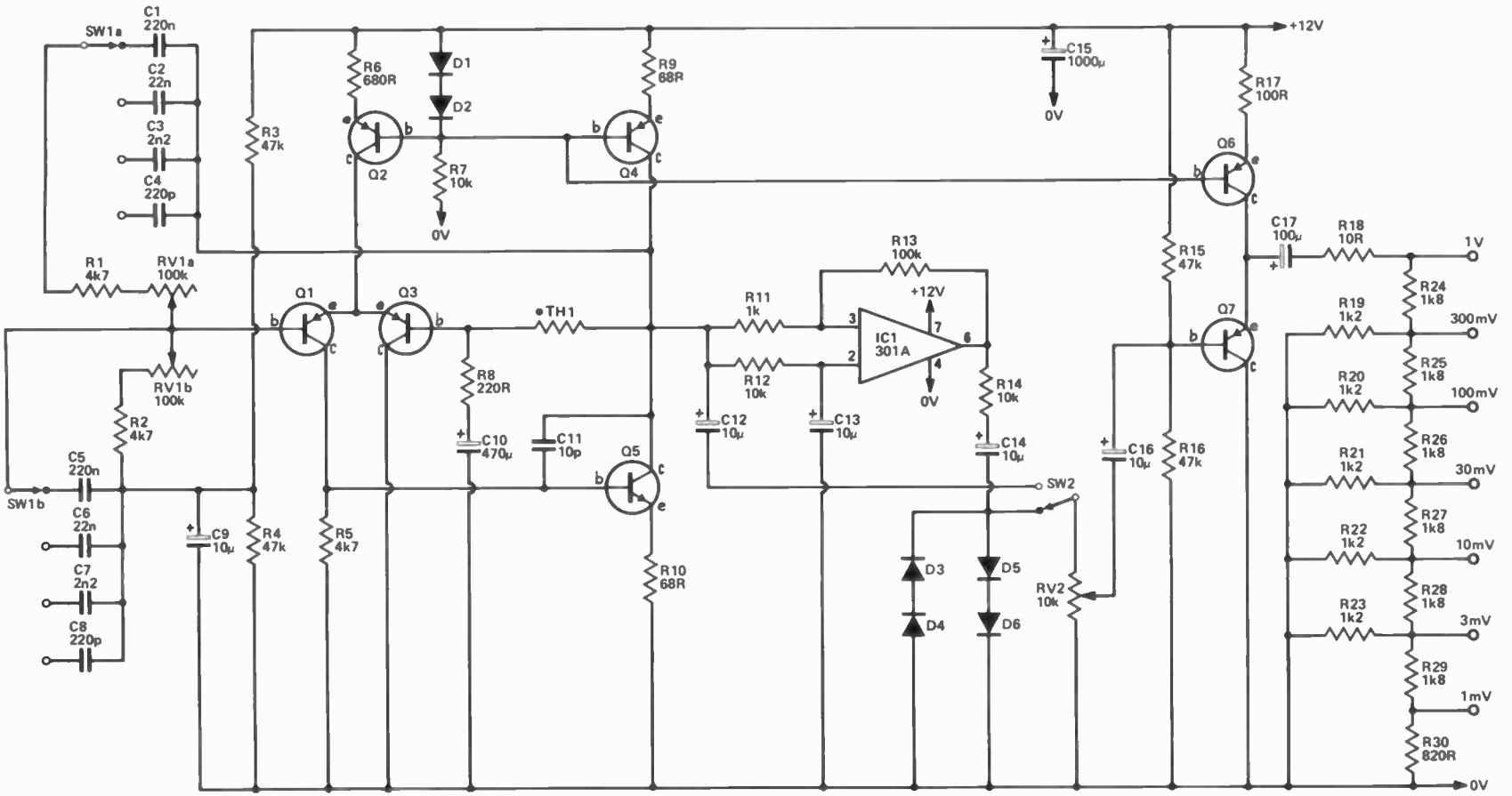


Fig. 2. The circuit diagram of the oscillator section.

World Radio History

crystal display, features low power consumption. Due to the method of conversion from period to frequency the range is limited from about 50 to 1999 counts and therefore automatic range selection is used. As the oscillator itself has less range than this, this limitation is no problem.

To simplify wiring we initially used CMOS analogue switches to select the range changing capacitors in the oscillator but this unfortunately increased the second harmonic distortion when the supply voltage dropped below 12 volts. This is due to the non-linearity of the "on" resistance when the input voltage changes. We therefore reverted to the good old mechanical switch!

Construction

Assemble the frequency counter board first, following the overlay provided. As this board is mounted very close to the front panel (only the height of the LCD) the capacitors should have leads long enough to allow them to be laid on their side on top of the resistors, etc. Also the CA3130 and the transistor will have to be mounted close to the board. While it is not essential that a socket be used (we didn't) for the LCD, one is recommended and although the Molex pins provided in the evaluation kit are not the best, they are available. Be very careful with the display as it is glass and therefore fairly fragile.

The oscillator board can now be assembled following its overlay diagram. The thermistor should be tied down using a loop of tinned copper wire and pc pins should be used on all external wire terminating points. Cut all leads short on the back of the pc boards as the two are mounted back-back with only 6 mm spacing.

We built the units into a large zippy box with all the components mounted on the front panel. The pc boards are secured by four 6BA c/s screws through the aluminium but hidden by the Scotchcal front panel used. The frequency meter board is spaced using 6BA nuts to give just enough clearance for the display and is held in place using 6.4mm long tapped spacers. Check that the spacers do not touch any tracks on the pc board and if so add pieces of insulation material under them.

The switches and potentiometers can now be mounted on the front panel and the wiring from the frequency counter board to the range switch done. Add wires from the two power connections and the input for later connection to the oscillator board.

Continued on page 22.

SPECIFICATION – ETI 137

Oscillator section	
Ranges	10.0 – 100.0Hz 100 – 1000Hz 1.00 – 10.00kHz 10.0 – 100.0kHz
Outputs available	sine or square
Output level	1V maximium continuously variable plus 10dB steps down to 1mV
Output impedance	nominally 600 ohms
Sine wave distortion	<0.1%
Square wave risetime	200ns
Frequency meter section	
Number of digits	3½
Display	LCD
Reading rate	5 per second
Resolution	0.1Hz on lowest range
Mode	Period measurment computed to read frequency
General	
Power consumpion	26mA @ 12V dc
Battery life	
Ni Cads	20 hours
Pencells (red)	30 hours
Pencells (alkaline)	50 hours

Printed circuit boards – page 129.

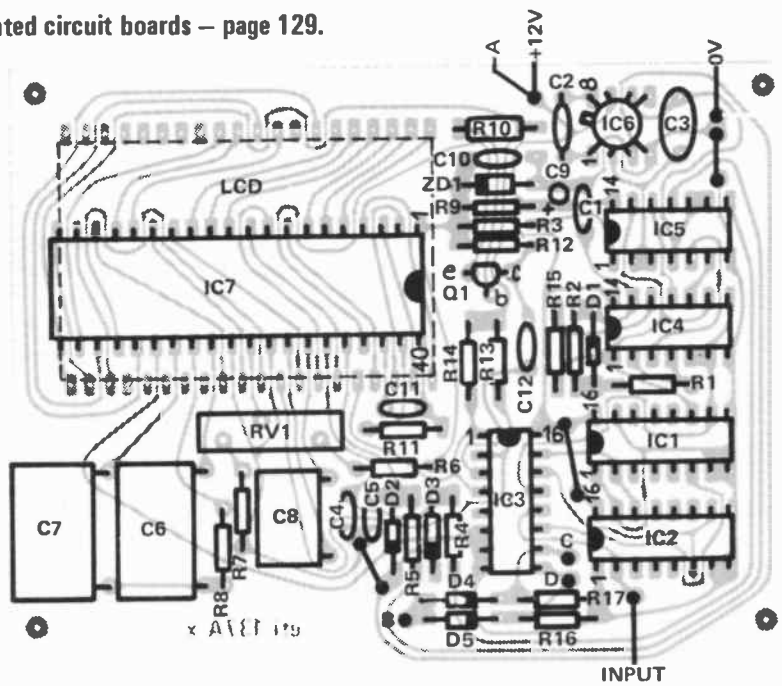


Fig. 3. Component overlay of the frequency meter board. Insert the LCD such that the +1 digit is on the left.

World Radio History

PARTS LIST – ETI 137

General
Plastic box UB
1 One pole 12 position rotary switch
1 Three pole 4 position rotary switch
2 STDP toggle switches
4 knobs to suit
12V battery (8xdry cell or 10xNicads)
External power socket
Scotchcal front panel
Wire, screws etc.

Frequency Counter Board – ETI 137A

Resistors all ¼W 5%
R1 . . . . . 10k
R2,3 . . . . . 1M
R4,5 . . . . . 1k
R6 . . . . . 10k
R7 . . . . . 1k
* R8 . . . . . 47k
R9 . . . . . 1k
R10. . . . . 4M7
* R11. . . . . 100k
R12. . . . . 100k
R13,14. . . . 4M7
R15. . . . . 1M
R16,17. . . . 100k

Potentiometer
* RV1 . . . . . 1k ten turn trim

Capacitors
C1. . . . . 330p ceramic
C2. . . . . 56p ceramic
C3. . . . . 100n polyester
C4,5 . . . . . 10n polyester
* C6. . . . . 470n polyester
* C7. . . . . 220n polyester
* C8. . . . . 100n polyester
C9. . . . . 1μ0 35V tantalum
C10. . . . . 10n polyester
* C11. . . . . 100p ceramic
C12. . . . . 10n polyester

Semiconductors
IC1,2 . . . . . 4518 (CMOS)
IC3 . . . . . 4052 (CMOS)
IC4 . . . . . 4001 (CMOS)
IC5 . . . . . 4016 (CMOS)
IC6 . . . . . CA3130
* IC7 . . . . . ICL7106
Q1 . . . . . BC549
D1–D5. . . . 1N914
ZD1. . . . . 10V 300mW Zener

Miscellaneous
PCB ETI 137A
* LCD display

* These parts are provided in the Intersil ICL7106 Evaluation Kit.

Oscillator Board – ETI 137B

Resistors all ½W 5%
R1,2 . . . . . 4k7
R3,4 . . . . . 47k
R5 . . . . . 4k7
R6 . . . . . 680R
R7 . . . . . 10k
R8 . . . . . 220R
R9,10. . . . . 68R
R11. . . . . 1k
R12. . . . . 10k
R13. . . . . 100k
R14. . . . . 10k
R15,16. . . . 47k
R17. . . . . 100R
R18. . . . . 10R
R19–R23 . . 1k2
R24–R29 . . 1k8
R30. . . . . 820R

Thermistor
TH1. . . . . type R53

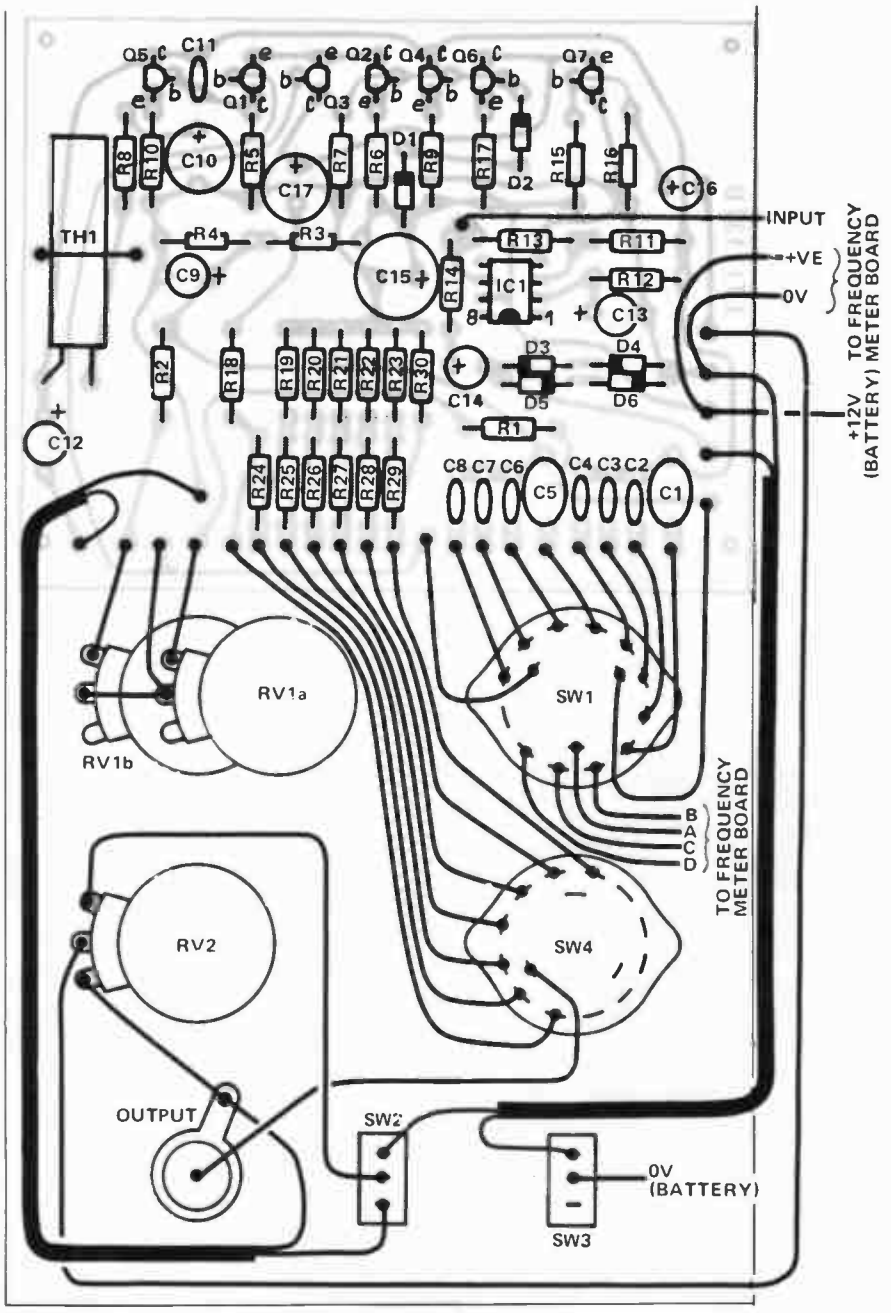


Fig. 4. The component overlay of the oscillator board and the wiring of the front panel.

Potentiometers
* RV1 . . . . . 100k dual rotary
RV2 . . . . . 10k lin rotary

Capacitors
C1. . . . . 220n polyester
C2. . . . . 22n polyester
C3. . . . . 2n2 polyester
C4. . . . . 220p ceramic
C5. . . . . 220n polyester
C6. . . . . 22n polyester
C7. . . . . 2n2 polyester
C8. . . . . 220p ceramic
C9. . . . . 10μ 25V electro
C10. . . . . 470μ 25V Electro
C11. . . . . 10p ceramic
C12–C14 . . 10μ 25V electro
C15. . . . . 1000μ 16V electro
C16. . . . . 10μ 25V electro
C17. . . . . 100μ 25V electro

Semiconductors
IC1 . . . . . 301A
Q1–Q4. . . . BC559
Q5 . . . . . BC549
Q6,7 . . . . . BC559
D1–D6. . . . 1N914

Miscellaneous
PCB ETI 137B

* RV1 – the preferred curve giving best resolution is antilog. If reverse rotation is acceptable log is as good. Otherwise use a linear curve.

World Radio History

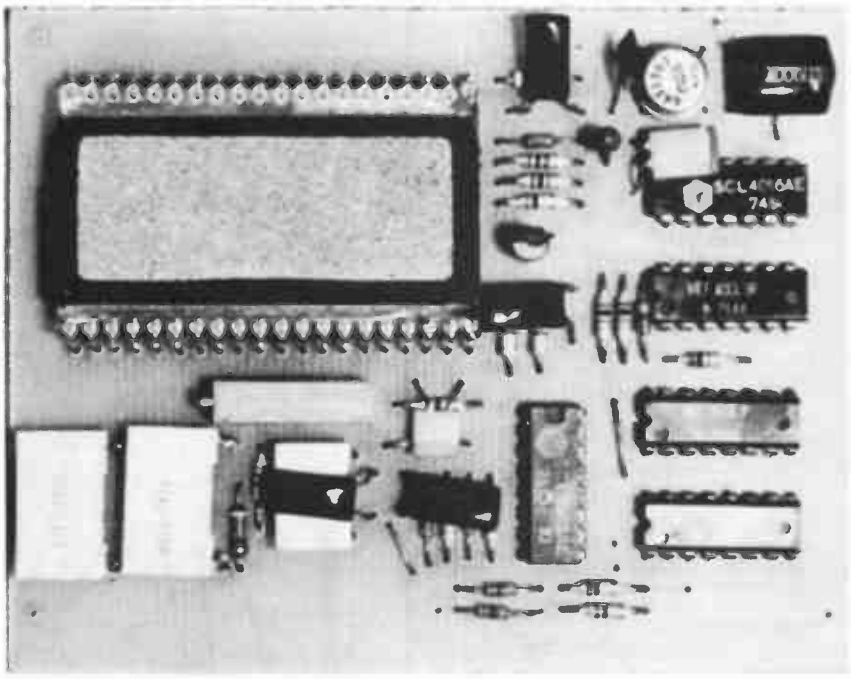
Project 137

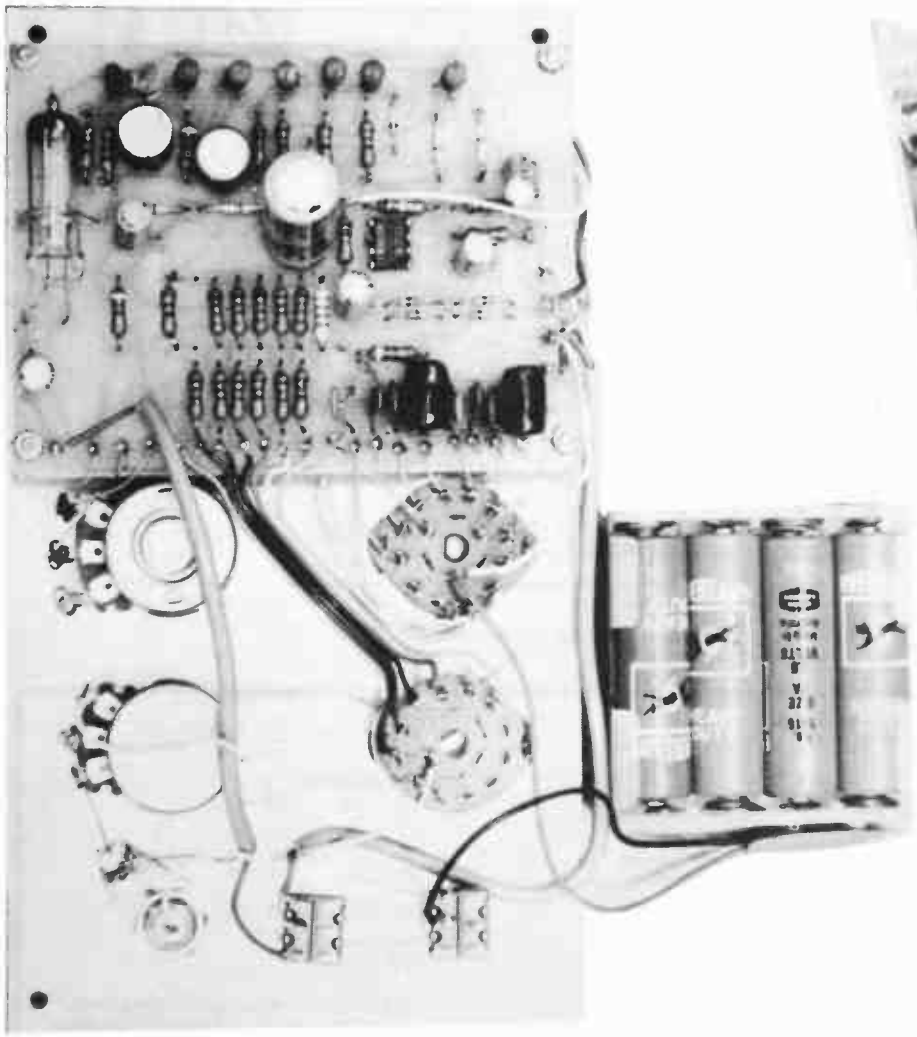
The oscillator board can now be mounted onto the back of the frequency meter board ensuring that no leads short between the two boards. Also check that the spacers do not touch any tracks on the oscillator board. The wiring of the front panel can now be completed.

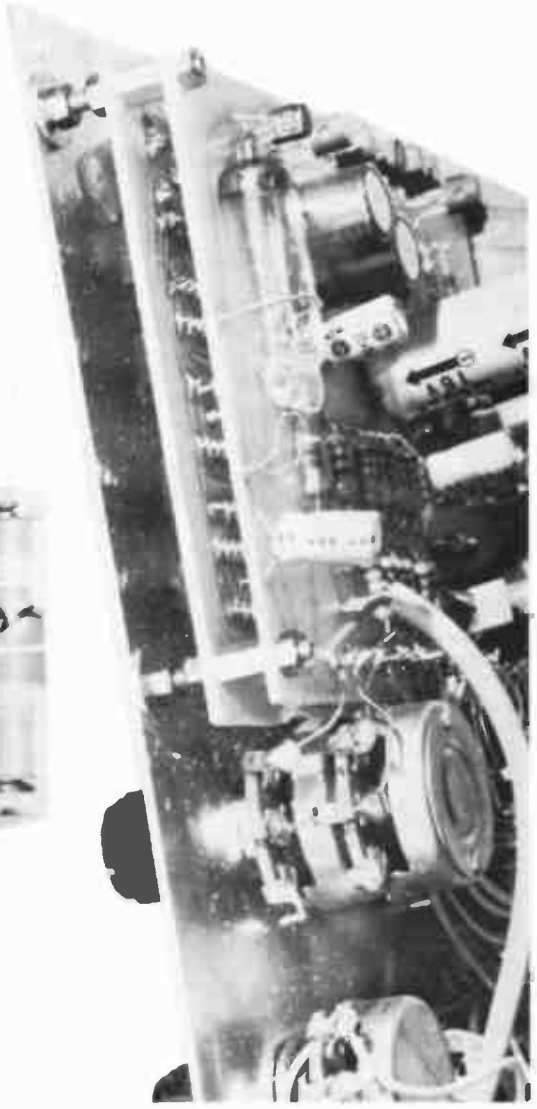
Checking and Adjustment

Switch on and check that the frequency meter and oscillator are working. Monitor the output of the oscillator with an accurate frequency counter and adjust the oscillator to the top end of one range. The frequency meter can now be calibrated by means of the 10 turn potentiometer on that board.

Check that the display range changes correctly and that the decimal point also moves. Each range while nominally having a 10-100 variation will be adjustable from about 7 to 150. Check the attenuator has 10 dB between steps.







World Radio History

Project 135

DIGITAL PANEL METER

This simple, economical yet highly accurate voltmeter uses a large liquid crystal display for easy reading and low power consumpion. It will be the basis of future projects as well as being a useful meter in its own right.

WE INITIALLY purchased a number of Intersil evaluation kits for our own use but soon realised that while they were very good electronically, the physical layout wasn't too hot. We therefore redesigned the PC board, reducing the size dramatically, adding the decimal point drive circuitry and some dropping resistors and zener diodes to allow the board to run from a dual power supply of +/– 5V or more (e.g. with op-amps). This resulted in a very useful device which we decided to run as a project. While it is basically a panel meter suitable for DC voltages and current (with a shunt) it will be the display module for several future projects.

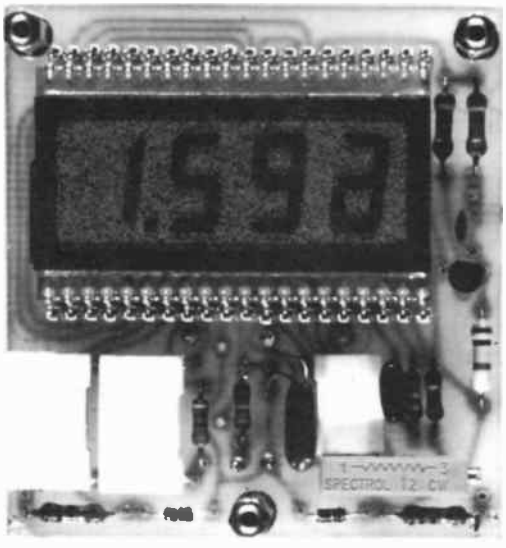
Construction

To save on real estate, the main IC is mounted under the display. We used the Molex connectors supplied with the evaluation kit for the display and soldered the IC directly into the board. If you want to mount the IC in a socket a low profile type should be used, with a high one for the display. As a socket is not available for the display a standard 40 pin one can be cut up to fit.

However before fitting either the display sockets or the IC, fit all the other components first. The overlay in fig. 3 shows the positioning of the components. Most of the components come with the evaluation kit. The large capacitors are laid on their side to minimise height.

When fitting the IC solder pins 1 and 26 first (the power supply pins) so that the protection diodes on the inputs can operate, thus preventing damage by static electricity. It is necessary that a small tipped iron and fine solder be used to prevent bridging tracks. The Molex sockets can now be fitted in two strips of 20 with the top connecting pieces being broken off using long nosed pliers after they are soldered in.

As there are no polarity marks on the display it is necessary to hold it at an angle to the light and look for the outline of the digits. The full format of the display is shown in fig. 2. In this unit the arrow, semicolon and the vertical part of the + sign are not used.



SPECIFICATION – ETI 135

Full scale reading	**200mV**
Resolution	**100μV**
Accuracy	**<1 digit**
Display	**3½ digit LCD**
Input impedance	**$>10^{12}$ ohms**
Input bias current	**≈2 pA**
Polarity	**automatic**
Conversion method	**dual slope**
Reference	**internal ± 100ppm**
Power supply	**±5V to ±15V dc 1mA @ ±5V**

World Radio History

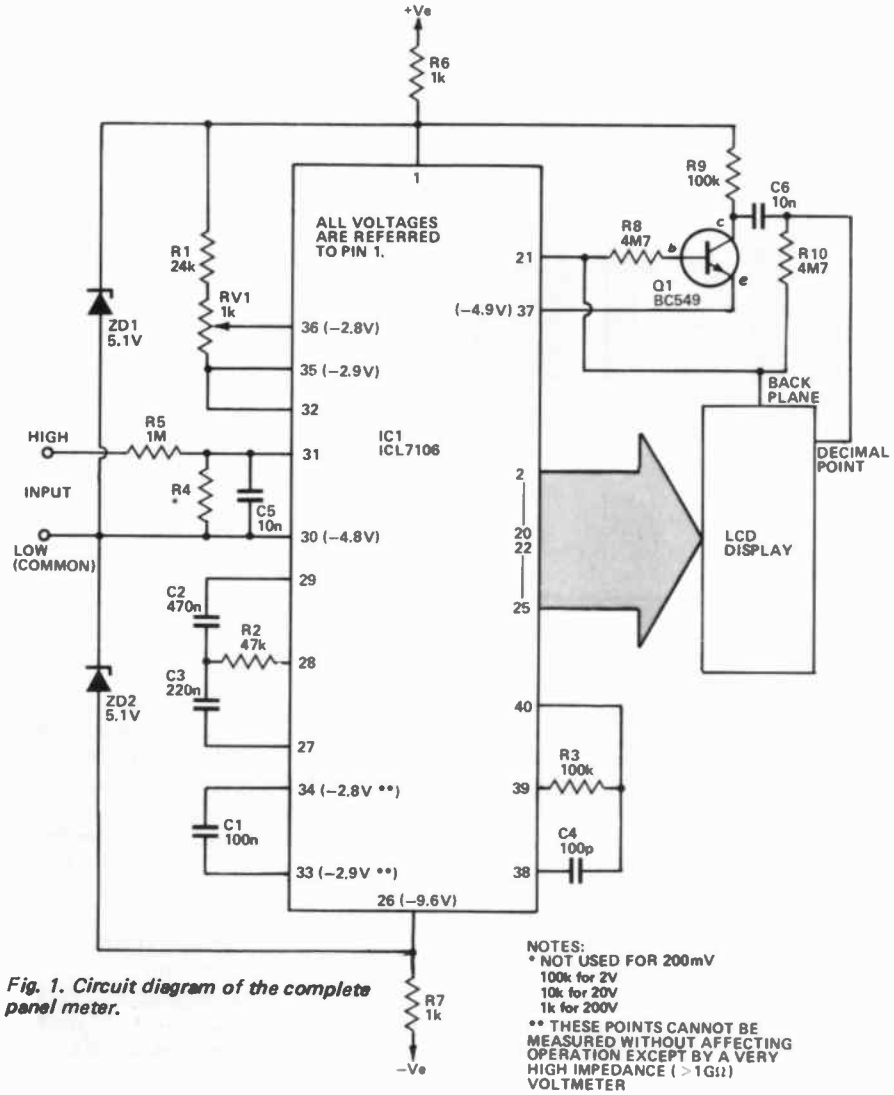


Fig. 1. Circuit diagram of the complete panel meter.

HOW IT WORKS – ETI 135

Not much can be said on how this project works as everything is done by one IC and if anything goes wrong it is usually the IC. We have included some waveform diagrams and voltages for reference purposes. The conversion works on the dual-slope integration technique, which is the most reliable of the simple methods available. A capacitor is charged up at a rate proportional to the input voltage for a predetermined time (in this case 1000 clock pulses), then it is discharged at a constant rate until it reaches the starting point again. The time taken to do this (i.e. the number of clock pulses) is proportional to the input voltage.

It is a true dual polarity system where the integration direction depends on the polarity of the input voltage. Provided AC ripple on the input averages to zero over 1000 clock pulses it will be rejected, hence where 50 Hz mains is to be rejected a 50 kHz clock should be used, giving 80 ms sample time (4 cycles of 50 Hz). The clock can be adjusted by varying R3 if desired.

The printed circuit board layout for this project is on page 126.

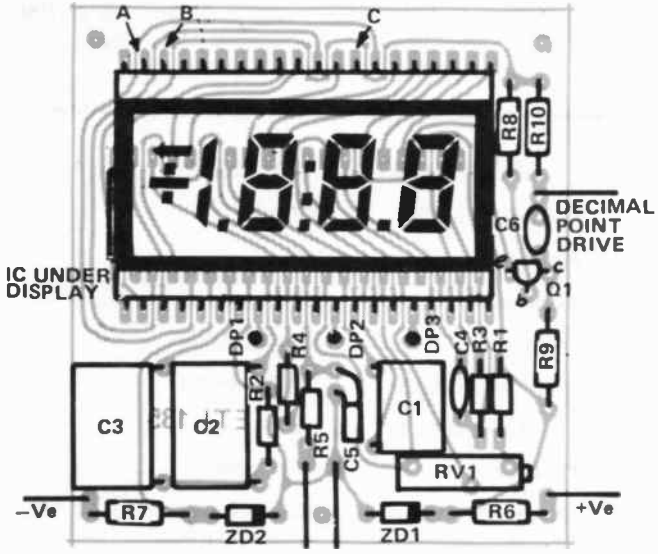


Fig. 2. Component overlay with the display in place. Points marked A, B and C are the unused display segments – the vertical part of the + sign, the arrow and the semicolon respectively.

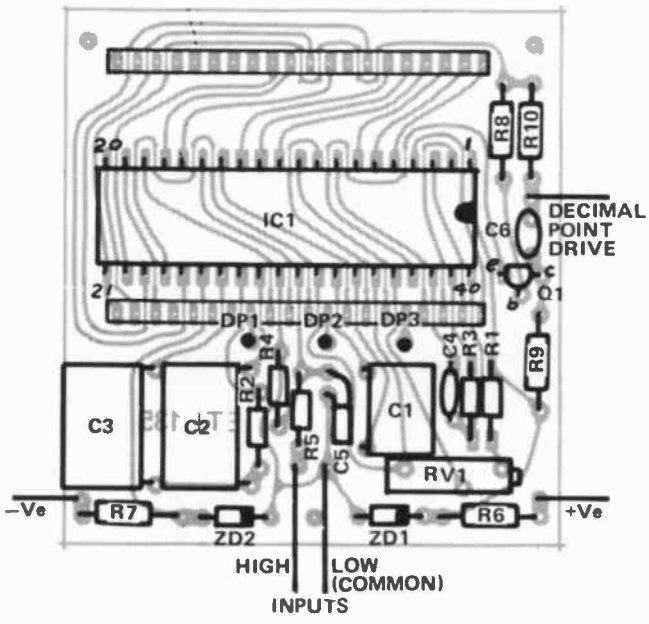


Fig. 3. The component overlay without the display showing the positioning of the integrated circuit.

World Radio History

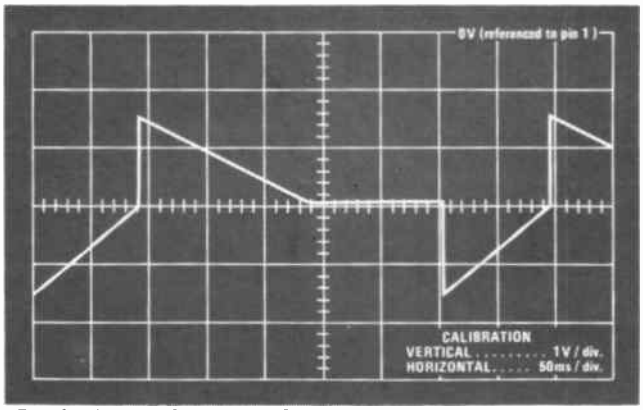


Fig. 4. The waveform at pin 27 with a negative input voltage of about 170mV.

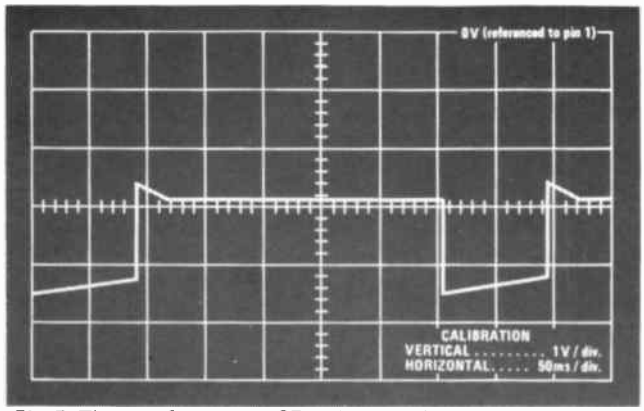


Fig. 5. The waveform at pin 27 with a negative input voltage of about 30mV. Compare this with Fig. 4.

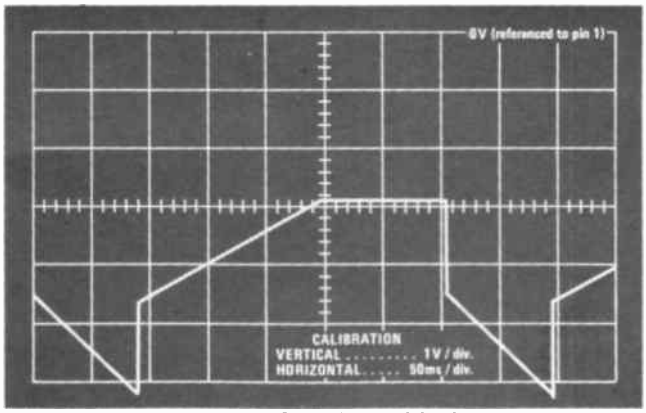


Fig. 6. The waveform at pin 27 with a positive input voltage of about 170mV.

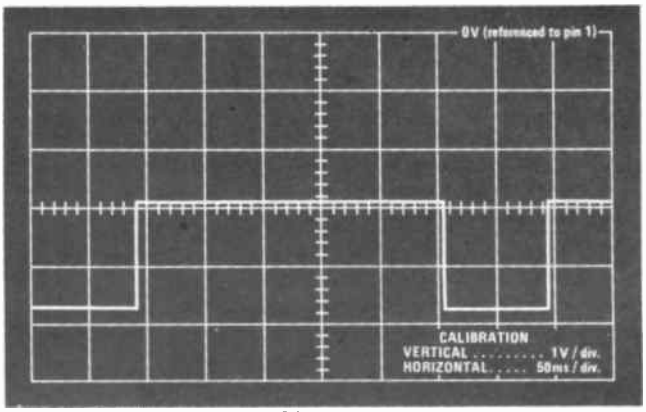


Fig. 7. The waveform at pin 28.

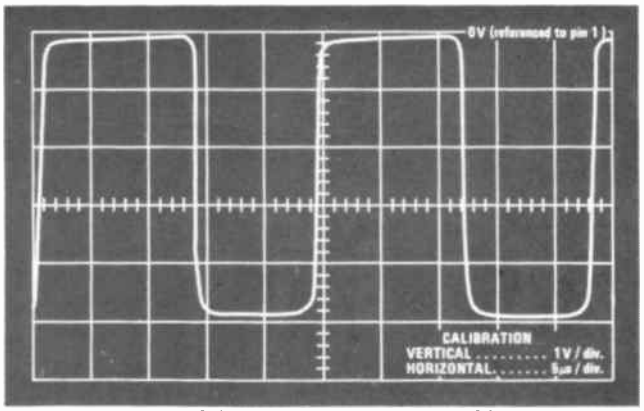


Fig. 8. The output of the master oscillator on pin 38.

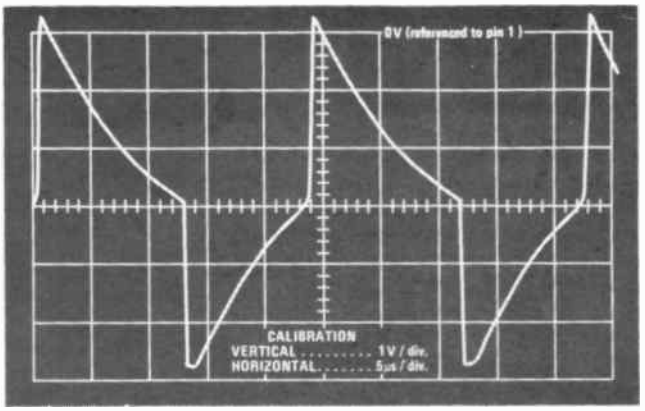


Fig. 9. The input of the oscillator – pin 40.

PARTS LIST – ETI 135

Resistors all ¼ or ½ W, 5%
R1*. 24k
R2*. 47k
R3*. 100k
R4 . . . . . see circuit diagram
R5*. 1M
R6 . . . . . 1k
R7 . . . . . 1k
R8 . . . . . 4M7
R9 . . . . . 100k
R10. . . . . 4M7

Potentiometers
RV1*. . . . . 1k 10 turn trim

Capacitors
*C1. . . . .100n polyester
*C2. . . . .470n "
*C3. . . . .220n "
*C4. . . . .100p ceramic
C5,6 . . . .10n polyester

Semiconductors
IC1* ICL7106
Q1 . . . . . BC549
ZD1,2 . . . . 5.1V 300mW

Miscellaneous
PC board ETI 135
LCD display
* Socket for LCD display

* These components are supplied with the Intersil ICL7106EV evaluation kit.

The Intersil evaluation kit which contains most of the components for this project is available from R & D Electronics, 23 Burwood Road, Burwood, Victoria 3125. Sydney address is 133 Alexander Street, Crows Nest, NSW. 2065.

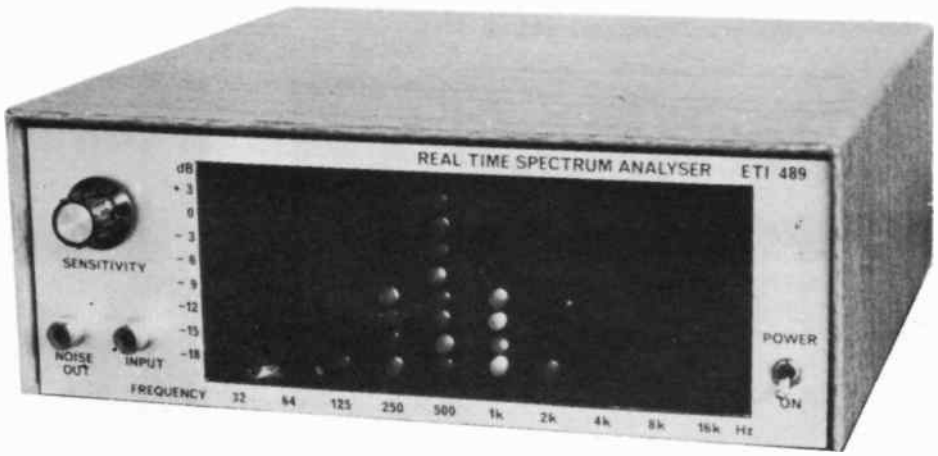
World Radio History

Audio Spectrum Analyser 2

LED display for compact, easy-to-build unit.

OUR PREVIOUS Real Time Audio Analyser design produced beautiful displays on the screen of an oscilloscope but this means, of course, that to use the device one has to have a scope. Not everyone has, and with this in mind, we contemplated the design of a more conventional analyser with LED bar-graph display. Urged on by reader response to our hint that this design was on the cards, we have gone ahead and produced the project in double-quick time.

This version has the great advantage of portability over the previous design, and also looks better than a scope sitting next to your brand new, 21st century styled hi-fi! It is also easier to set up and trouble-shoot.



Design Features

When we proposed a LED version of the spectrum analyser we initially were going to use the original filter board and design a new logic board which multiplexed the LED display. The only question at that time was whether to multiplex the LEDs as columns or as individual LEDs. The column method is easier on the power supply as the peak current is only 10 times the average current while singly the peak current is 80 times the average. This is not quite accurate because a multiplexed LED requires less average current for the same output than one continuously on. However the column method also requires one extra diode per LED to give the isolation required between columns.

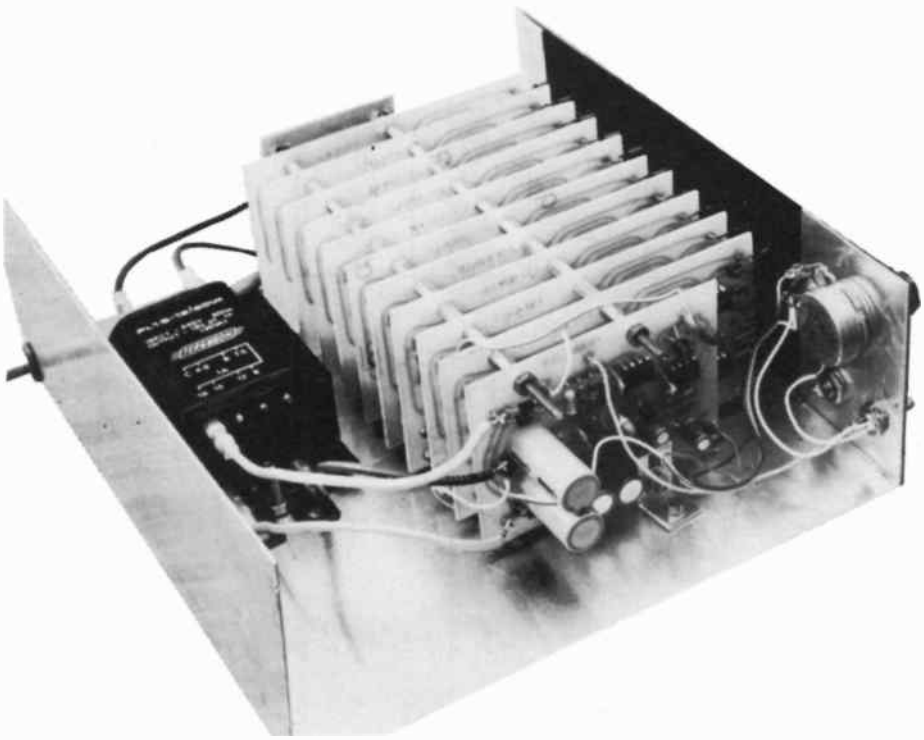
SPECIFICATION – ETI 489

No. of bands	10
Frequencies	31, 63, 125, 250, 500, 1k, 2k, 4k, 8k, 16k
Filter characteristics	−12dB, one octave from nominal centre frequency
Display	LED display 3dB spacing
Input level	50mV – 10V
Input impedance	47k
Pink noise output	200mV

World Radio History

After struggling with the PC board layout which was developing into a double sided board similar to the filter board of the previous analyser, we decided there must be an easier way to make a living! The question was then raised of whether it was worthwhile to multiplex the display at all and the answer was the project as it appears here.

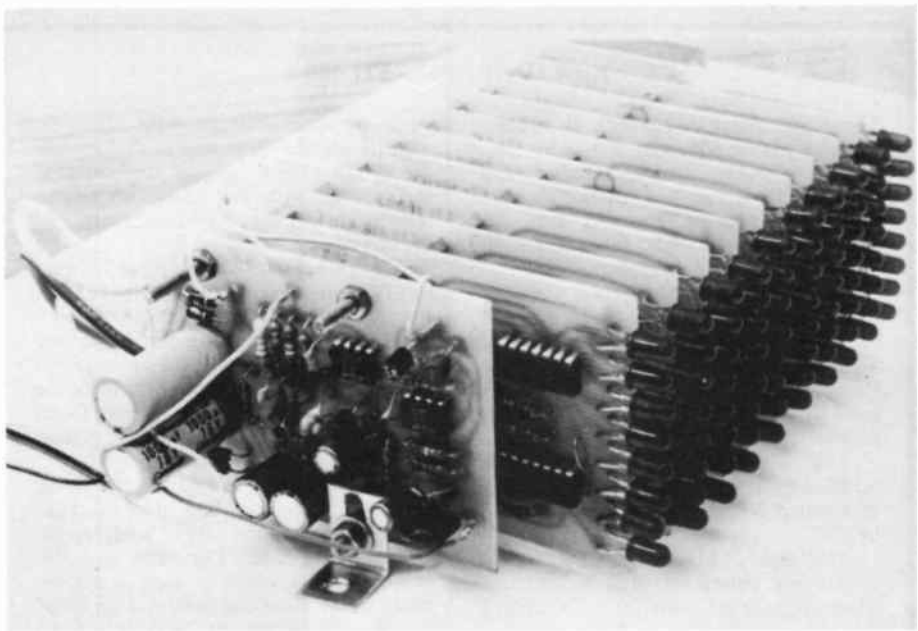
The individual board approach not only makes fault finding easier and less likely, it also allows single sided PC boards to be used throughout. The system can also be expanded (or cut down) as desired simply by changing the filter components and the number of display boards. The power supply is capable of supplying up to 20 display boards without increasing the filter capacitors.



Construction

Assemble the power supply board and the ten filter display boards with the aid of the overlays. The filter components can be selected from Table 1 noting that when the tantalum capacitors are used in the three lower octaves a bias resistor R15 is needed. The LEDs should be installed as evenly as possible with the polarity correct.

We assembled the units on 1/8" brooker rod with 12.5mm spacers between the boards. Metal brackets are used at each end to support the assembly. On the filter display boards the power rails and the input are all common and for the power supply we used long lengths of tinned copper wire threaded through the holes. The input lead should be done with separate links to allow the units to be serviced later if needed.



Before assembling the unit however each board should be checked with an oscillator to check it for the correct frequency and to adjust the calibration potentiometer. This is best done by measuring the sensitivity of the 16 kHz board with RV2 set for maximum sensitivity and adjusting all the others till they are the same.

We made a metal box with a piece of red perspex for a window to house the unit. If it is to be used with an equaliser (such as the ETI 484) it could be built into the same box.

It will be found with the economical LEDs available that there will be a difference in brilliance between them. If desired matched LEDs are available but not for 20 cents each!

World Radio History

Project 489

TABLE 1

Centre frequency	R15	C14,C15 tantalum	C16 polyester	C17 polyester
32	1M	3μ3	–	68n
63	1M	1μ5	–	33n
125	1M	1μ0	–	18n
250	–	–	220n	8n2
500	–	–	100n	3n9
1k	–	–	47n	2n2
2k	–	–	27n	1n0
4k	–	–	12n	560p
8k	–	–	6n8	270p
16k	–	–	3n3	150p

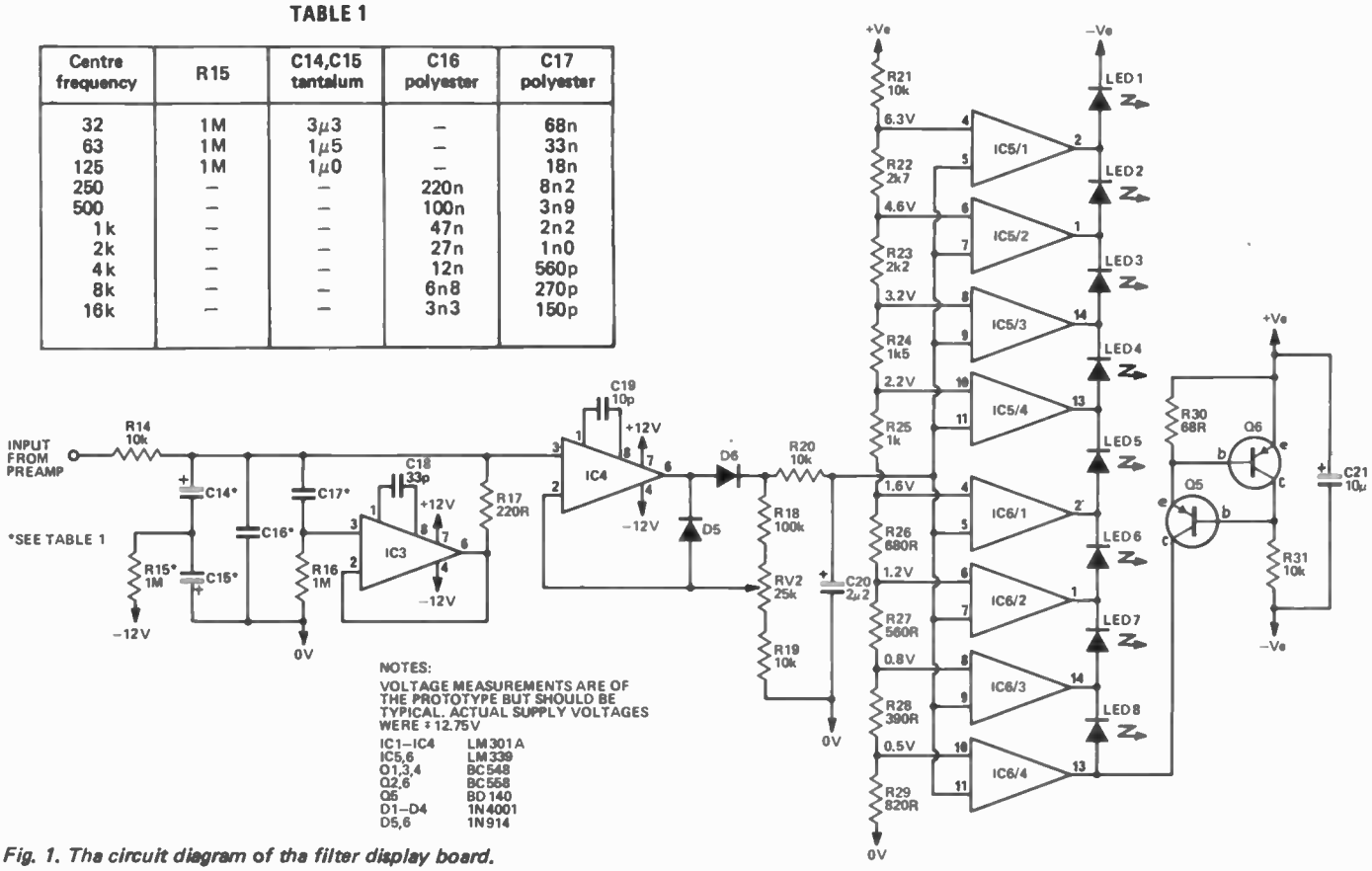


Fig. 1. The circuit diagram of the filter display board.

HOW IT WORKS – ETI 489

The input signal to the unit is initially buffered and amplified by IC1 and is then split into octave bands, rectified and displayed by a "bar" of LEDs. We have used 10 separate boards for the rectifier-display as only the component values in the filter are different.

The filter is a parallel LC network where the inductive part is a gyrator formed by IC3, C17, R16 and R17. The value of such an "inductor" is R16 x R17 x C17 Henrys (C17 in Farads). This, with the parallel capacitor C16 and the series resistor R14, form a band pass filter.

The output of the filter is half wave rectified by IC4 which also provides a gain of about 5 before the signal is smoothed by C20.

The eight LEDs in each individual display are connected in a series chain which is supplied with 10 mA by the constant current source Q5, Q6. Control of how many LEDs will be on is done by IC5 and IC6. These are quad voltage comparators which have as the output stage an open collector NPN transistor with its emitter connected to the negative supply rail. These compare the output of the rectifier with the voltage set on the resistive divider R21-R29 and "short" out the unwanted LEDs.

The power supply is a simple fullwave rectified with a centre tap giving ±12 V dc. Due to the load (about 150 mA) there is about one volt ripple on the supply rail but this does not affect the operation of the unit. As the current drawn by the filter display boards does not change with the number of LEDs on the supply voltage remains reasonably constant.

The 100 Hz ripple does however affect the noise generator and this has been changed from the 487 analyser to accommodate this. The noise generator consists of Q3 which is used as a zener diode where the noise current is amplified by Q4. The output of Q4 is white noise and to give pink noise a 3 dB/octave filter is needed. IC2 and the associated capacitors and resistors provide this filter.

PARTS LIST – ETI 489A

Filter–Display boards 10 required

Resistors all ¼W 5%
- R14. . . . . 10k
- R15. . . . . see table 1
- R16. . . . . 1M
- R17. . . . . 220R
- R18. . . . . 100k
- R19–R21 . . 10k
- R22. . . . . 2k7
- R23. . . . . 2k2
- R24. . . . . 1k5
- R25. . . . . 1k
- R26. . . . . 680R
- R27. . . . . 560R
- R28. . . . . 390R
- R29. . . . . 820R
- R30. . . . . 68R
- R31. . . . . 10k

Potentiometers
- RV2 . . . . . 25k trim

Capacitors
- C14–C17 . . see table 1
- C18. . . . . 33p ceramic
- C19. . . . . 10p ceramic
- C20. . . . . 2μ2 25V electro*
- C21. . . . . 10μ 25V electro*

Semiconductors
- IC3,4 . . . . . LM301A
- IC5,6 . . . . . LM339
- Q5 . . . . . BD140
- Q6 . . . . . BC558
- D5,6 . . . . . 1N914
- LED1–LED8

Miscellaneous
- PC board ETI 489A

World Radio History

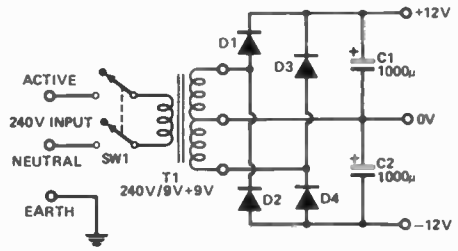


Fig. 2. The power supply circuit.

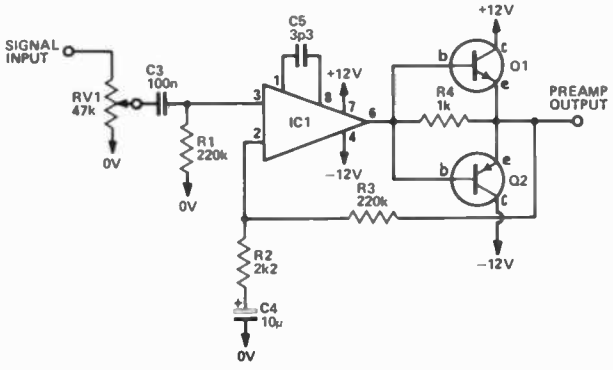


Fig. 3. The circuit of the preamplifier–buffer.

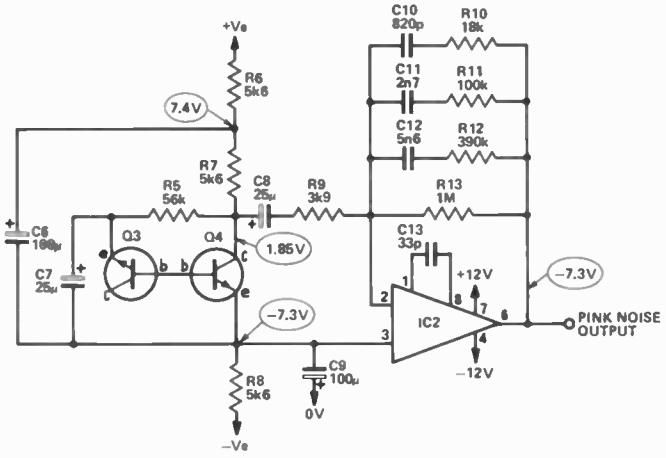
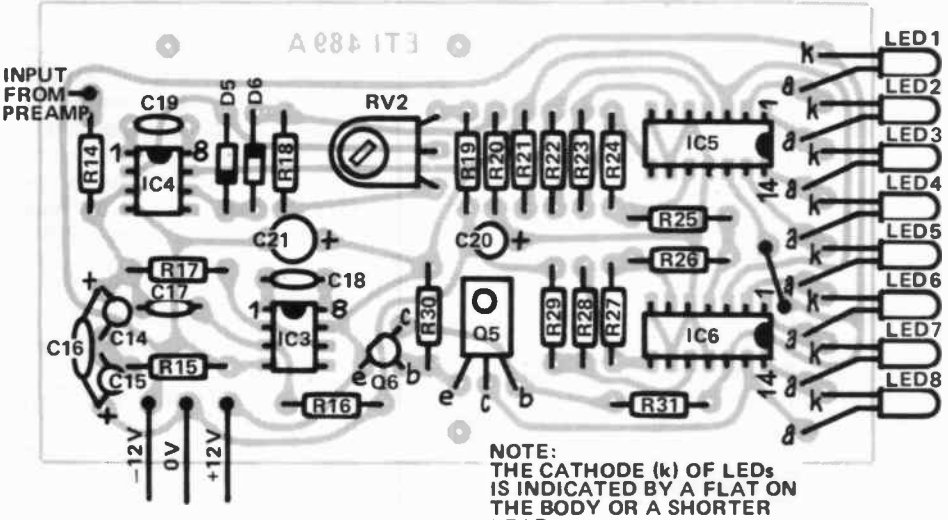


Fig. 4. The circuit diagram of the pink noise generator.



NOTE:
THE CATHODE (k) OF LEDs IS INDICATED BY A FLAT ON THE BODY OR A SHORTER LEAD.

Fig. 6. The component overlay of board A.

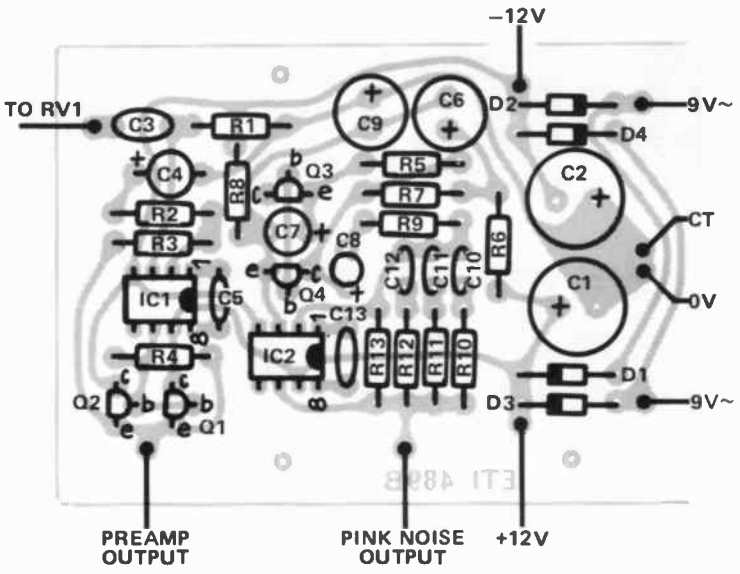


Fig. 5. The component overlay of board B.

The printed circuit boards for this project are on page 16.

PARTS LIST – ETI 489B

Power Supply board

Resistors all ½W 5%
R1 . . . . . 220k
R2 . . . . . 2k2
R3 . . . . . 220k
R4 . . . . . 1k
R5 . . . . . 56k
R6–R8. . . . 5k6
R9 . . . . . 3k9
R10. . . . . 18k
R11. . . . . 100k
R12. . . . . 390k
R13. . . . . 1M

Potentiometers
RV1 . . . . . 47k log rotary

Capacitors
C1,2 . . . . . 1000µ 16V electro*
C3. . . . . 100n polyester
C4. . . . . 10µ 25V electro*
C5. . . . . 3p3 ceramic
C6. . . . . 100µ 25V electro*
C7,8 . . . . . 25µ 25V electro*
C9. . . . . 100µ 25V electro*
C10 . . . . . 820p ceramic
C11 . . . . . 2n7 polyester
C12 . . . . . 5n6 polyester
C13 . . . . . 33p ceramic

Semiconductors
IC1,2 . . . . . LM301A
Q1 . . . . . BC548
Q2 . . . . . BC558
Q3,4 . . . . . BC548
D1–D4. . . . 1N4001

Miscellaneous
PC board ETI 489B
Transformer 240V/9V+9V PL18/20VA
SW1 DPDT 240V toggle switch
Case to suit

*all electrolytic capacitors PC board or single ended type.

World Radio History

Project 138

AUDIO POWER METER

This design multiplies voltage and current to come up with the correct value of power, using an analogue multiplier IC.

POWER IS PROBABLY the least understood and most misrepresented quantity in the electrical measurement system. This is especially so in the area of audio amplifier and speaker specifications when terms like peak, peak to peak, music and RMS are related to power.

Power is simply the rate at which energy is being used. It is expressed in watts and the value may vary from femtowatts (10^{-12} W), as in the input power of a FET, to thousands of megawatts in the power generation field. The term thousand megawatts is generally used in preference to the more correct term, gigawatts.

Power can be calculated simply by multiplying voltage and current:

$$P = EI$$

In a dc circuit where both voltage and current remain constant no problem arises. However in an ac or a dc circuit where the voltage is not constant with time, this formula only holds for instantaneous power as the power varies with time. Power as we usually use the term is the time average of this. If the load is resistive, i.e. contains no inductance or capacitance, and we can measure the RMS value of the voltage, we can still use this simple formula. However measuring the RMS voltage is not easy as most voltmeters measure the peak or average rectified voltage with a suitable scaling factor built in to give a correct result when measuring a sine wave signal.

If the load is reactive the current and voltage will no longer be in phase, i.e. the peaks do not occur at the same point in time. The difference can be expressed either by the phase angle in degrees or by the cosine of this angle (known as the power factor). The current waveform can either be ahead of the voltage (leading) or behind it (lagging). Capacitive circuits give rise to a leading power factor while inductive circuits lag.

If working with a sine wave, and if the power factor is known, the formula for power can be expressed as:

$$P = EI \cos \phi$$

where ϕ is the phase angle. In a dc circuit $\cos \phi$ is unity so the formula holds for this case as well. An example is a 40 W fluorescent light which takes 430 mA from the 240 V mains. At first sight, this implies a power consumption of over 100 W, until it is realised that its power factor is about 0.45 lagging. The formula above, using $\cos \phi = 0.45$, thus gives a power consumption of only 46.4 W. (The additional 6 odd watts is dissipated in the ballast). The product of voltage and current is known as the VA rating and is used when calculating the currents in a circuit. If a capacitor is connected across a sine wave ac circuit the current taken can be calculated by dividing the voltage by the reactance of the capacitor. While this circuit draws current, it has a power factor of very near zero (90° phase lead) and therefore takes no power! By adding the correct amount of capacitance to an inductive circuit (i.e. the fluorescent light) the power factor can be altered, reducing the current drawn (but not the power).

Confused yet?

Getting back to audio amplifiers and their ratings, the problem lies in the complex nature of the music waveform and how to specify the amplifier's rating. As the waveform is far from a constant sine wave with the peak power being anything up to 20 times the average, numerous methods such as peak power, peak to peak power, music power, etc. evolved. However, for a long time there was no set standard, and one amplifier advertised with a 50 W (music) rating was in fact a 5 W stereo amplifier. The situation got so out of hand that the US Government brought down legislation on how amplifiers were to be tested. This is with a continuous sine wave signal with level set so that the distortion is at a specified level and power calculated from the RMS output voltage: hence the term RMS power. Note however that the term RMS refers to the method of measurement, i.e. the use of RMS voltage, and it is not the RMS value of the power waveform. It is, in fact, the average of the power waveform.

Speakers are just as confusing. They are normally specified not in terms of the power they can dissipate, but the maximum power of amplifier they are suitable for. This is due to the fact that music is never (well, rarely) a

World Radio History

SPECIFICATION – ETI 138

Power range	30mW – 3000W FSD in eleven ranges
Input impedance	
1V	47k
3V–300V	100k
10A	0.1 ohm
3A	0.32 ohm
1A	1 ohm
0.3A	3.2 ohm
0.1A	10 ohms
0.03A	32 ohms
Overload capability	
Voltage ranges	RMS – 200% peak – 300%
Current ranges	RMS – 100% peak – 300%
Accuracy	< 5%
Frequency range	dc to 100kHz

continuous sine wave and the average power in the speaker may be only 10% of the RMS rating of the amplifier, even with the amplifier clipping.

To measure the power actually being delivered to the speaker under music conditions, a wattmeter must be used.

Design Features

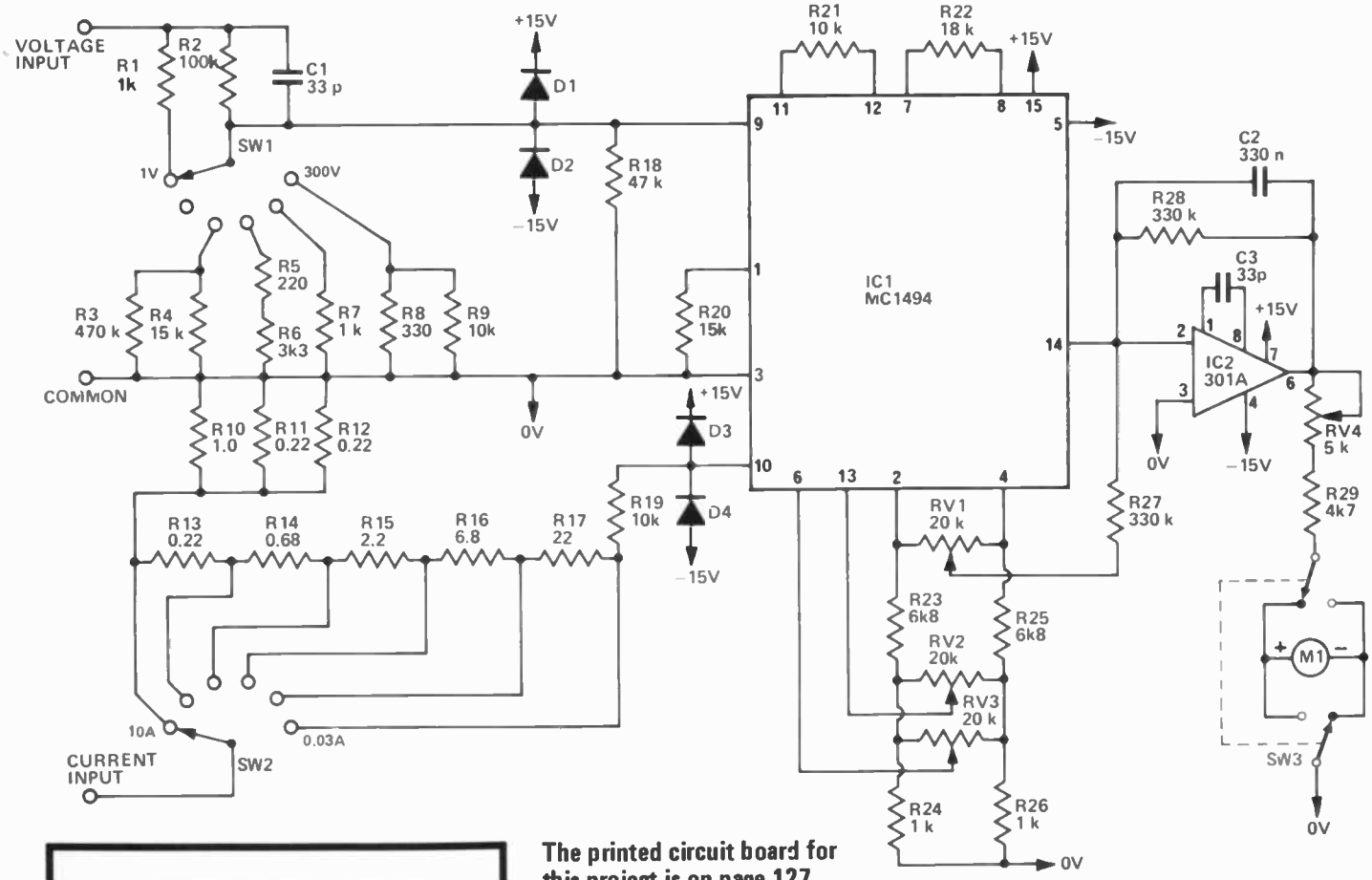
To multiply current and voltage together we had the choice of analogue or digital techniques. Unfortunately while digital is the 'in' thing, offering versatility and accuracy, it is not fast enough to calculate the instantaneous power on high frequencies. We therefore chose the analogue method.

Looking around for ICs, the only ones with reasonable price and availability were the MC1494, 1495 and 1496. The 1496 (or 796) is the cheapest and most readily available, but has the disadvantage of not being able to multiply dc signals or ac signals with a dc offset. The 1494 and 1495 are about the same price (around $7.00), and of the two, the 1494 was more linear and easier to use.

We chose not to use any input buffer on the voltage input but had to pay the penalty of having a lower input impedance than normal with voltmeters.

World Radio History

Project 138



The printed circuit board for this project is on page 127.

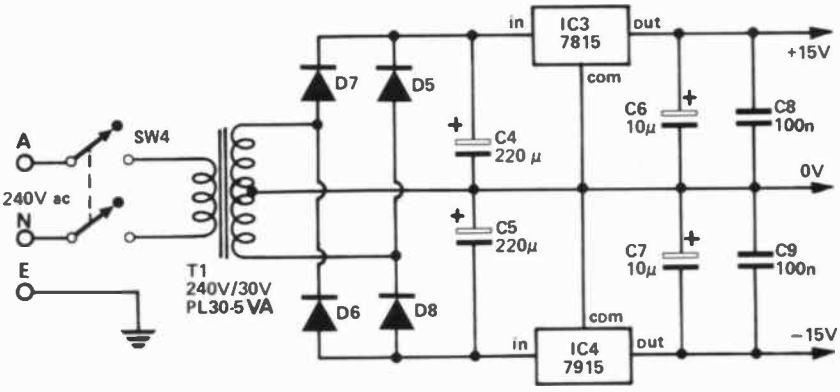
HOW IT WORKS – ETI 138

Power is the product of current and voltage. This holds irrespective of the nature of the load, provided you are talking about instantaneous power. By multiplying current and voltage together and then taking the average of these instantaneous values we find the true power. Again this works irrespective of the load.

In this circuit the multiplying is done by IC1 (MC1494), the output of which is a current proportional to the product of the inputs. For more detailed notes on this IC, see the separate section. The current output of this IC is converted to a voltage by IC2 with C2 providing the averaging. The meter is then simply wired across the output of this IC with a meter reversing switch provided. This reversing switch is needed not to measure negative power, but to correct for reversed readings due to differing external connections.

The power supply is a full wave bridge with a centre tap giving about ∓20 V dc which is then regulated to the ∓15 V required by IC1.

Adjustments for zeroing the voltage and current inputs are provided by RV2 and RV3 while RV1 compensates for offsets in the output. These are supplied by a stable ∓4 V reference in IC1. Range switching is done by SW1 and SW2. Protection against overvoltaging the IC is provided by D1 – D4.



F1g. 1 The circuit diagram of the audio power meter.

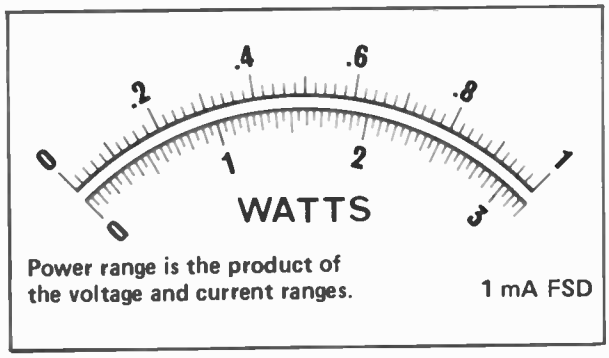


Fig. 2 The meter scale used. It is designed for the TD86 meter.

World Radio History

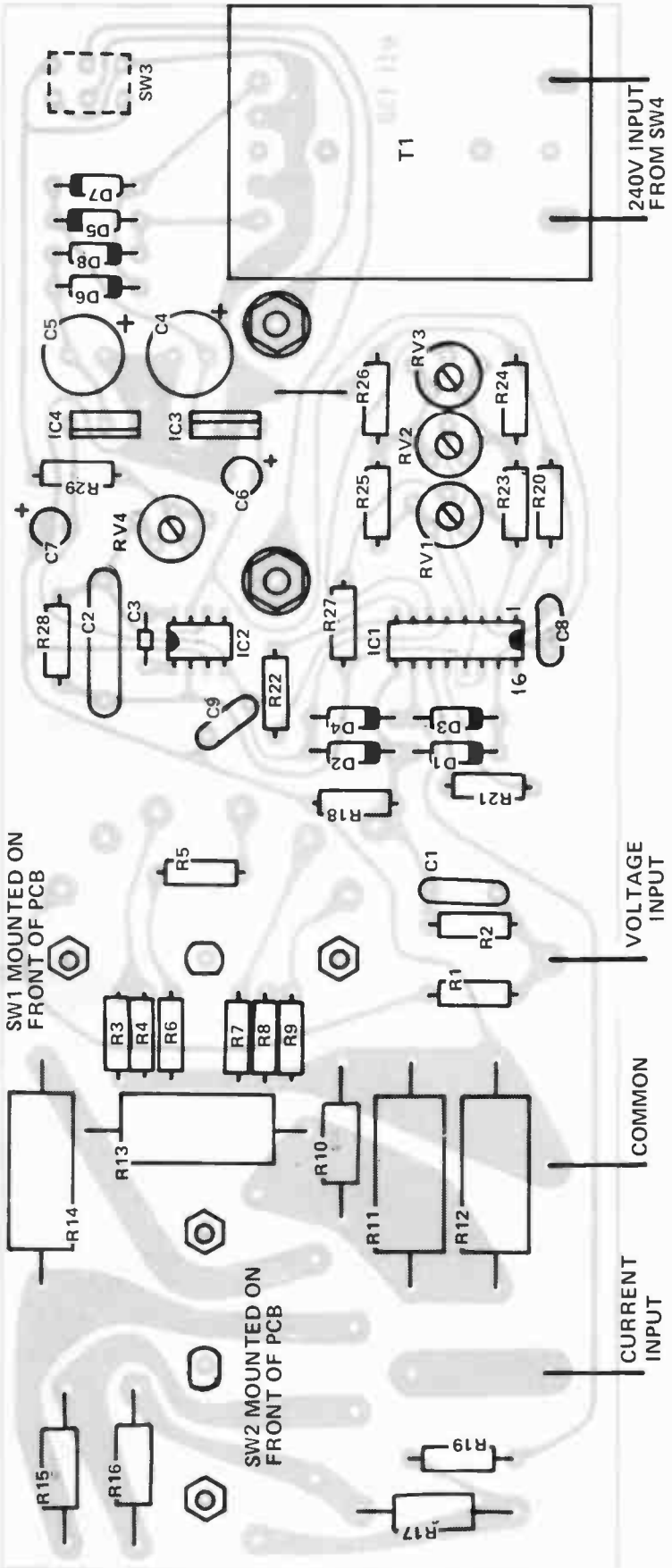


Fig. 3. The component overlay of the power meter.

PARTS LIST – ETI 138

Resistors all ½% 5W unless stated

R1	1k
R2	100k
R3	470k
R4	15k
R5	220R
R6	3k3
R7	1k
R8	330R
R9	10k
R10	1 ohm 1W
R11–R13	0.22 ohm 5W
R14	0.68 ohm 5W
R15	2.2 ohms 1W
R16	6.8 ohms 1W
R17	22R
R18	47k
R19	10k
R20	15k
R21	10k
R22	18k
R23	6k8
R24	1k
R25	6k8
R26	1k
R27, 28	330k
R29	4k7

Potentiometers

RV1–RV3	20k trim
RV4	5k trim

Capacitors

C1	33p 500V ceramic
C2	330n polyester
C3	33p ceramic
C4, 5	220µ 35V electro
C6, 7	10µ 25V electro
C8, 9	100n polyester

Semiconductors

IC1	MC1494
IC2	301A
IC3	7815
IC4	7915
D1–D4	1N914
D5–D8	1N4004

Miscellaneous

- PC board ETI 138
- SW1, 2 two pole 6 position 10A rotary switches (Paton Electrical)
- SW3, 4 two pole toggle switches
- Transformer PL30/5VA
- Meter 1mA FSD (TD86)
- Three binding posts
- Instrument case 255x100x205mm
- Power cord and clamp
- Two knobs
- Front panel

World Radio History

Using the Power Meter

To use the meter we must measure both voltage and current. There must be a common point for these measurements. The current connection can be in either of two ways as shown in the drawings below. One measures the power out of the supply and the second the power into the load. The difference? The current shunt in the wattmeter drops one volt when working at the full range value and this may or may not affect the reading. At 10 A this accounts for 10 W which, if the power being measured is only 100 W, is a 10% error – although if the measured power is 2400 W the error is only 0.4%.

The range of the meter is the product of the individual ranges, i.e. on 30 V and 1 A the fsd is 30 W, while 30 V and 3 A gives 100 W fsd. To help give a reading reasonably high on the scale, the voltage range can be overvoltaged by a factor of 2. Due to power dissipation problems this should not be attempted on the current ranges. The peak voltage or current can be as high as three times the range value.

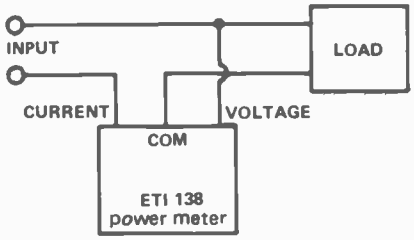


Fig. 4 This connection measures the power into the load.

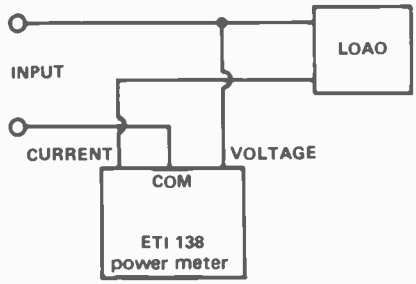


Fig. 5 This connection measures the power out of the supply.

Construction

We mounted all the components associated with the meter and the switches on a single pc board and if the same or similar case is to be used this is recommended.

Except for the meter and the switches the components are mounted on the 'normal' side of the pc board. These should be mounted first with the only critical part of the assembly in the area of the range switches. Here the high powered resistors should be spaced at least 5 mm from the pc board as they run hot at maximum current. Also the leads of all the resistors in this area should be cut off close to the pc board after soldering. This is to give adequate clearance to the rotary switches. We used two self tapping screws into the plastic of the transformer case to help fix it onto the board. We have made allowance for either the cermet (VTP) or the normal carbon trim potentiometer.

The switches used are made by Paton Electrical Pty. Ltd of 90 Victoria St., Ashfield, NSW, and were chosen as they are rated for 10 A 240 V operation. If desired the voltage switch may be the normal type rotary switch which will reduce the cost a little. As supplied, these switches have a bakelite brace at the rear to give support. We undid the nuts and removed this piece (carefully as the switch may spring apart) and then fitted it to the copper side of the board, retained by the nuts. The pc board then acts as the the rear support for the switch. A glance at the photographs of the unit should make this clear. Rotate the switch and check that the contacts do not touch any of the solder joints on the PC board. The contacts can now be wired to the pc board using heavy tinned copper wire for the current switch as there is up to 10 Amps flowing.

Mount the meter onto the front panel along with the two toggle switches and the binding posts. Remove the nuts from the voltage switch, leaving one on the current switch and then mount the pc board onto the meter. Run the nut on the current switch up to the back of the front panel and then fit the second nut on the the front side.

The toggle switches can now be wired along with the power wiring, fitting the knobs ready for calibration.

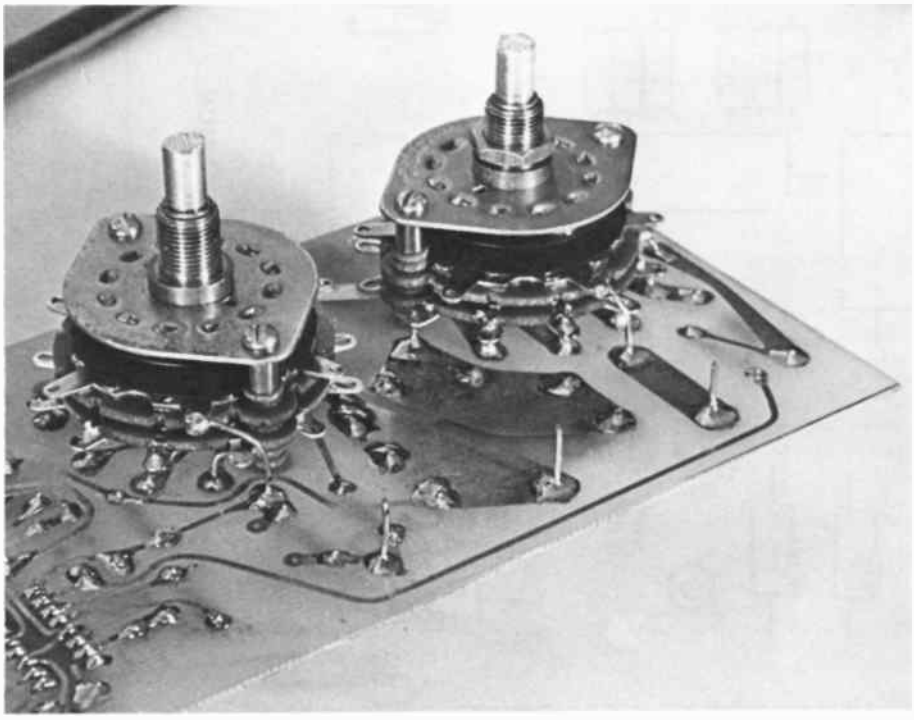
Calibration

Four adjustments are required, which are performed as follows:

Select the 1 V and 0.03 A ranges and switch on. If the meter reads in reverse, toggle SW3. Don't worry about the reading unless it is off scale. If it is, adjust RV1 to bring it back towards zero. Now apply a voltage of about 1 V dc to the voltage input and note the meter deflection. Adjust RV2* until there is no deflection when this voltage is applied. Now apply the voltage to the current input (it will take about 30 mA) and adjust RV3 until there is no deflection. Recheck the voltage input and readjust if necessary.

Now with no voltage applied adjust RV1 to give zero output. Apply exactly 1 V to both current and voltage inputs and adjust RV4 to make the meter read FSD.

This is all the calibration that should be necessary.



World Radio History

About the 1494

The 1494 is a variable transconductance multiplier with a bidirectional current source output. What this means is that it looks at the voltage on the two inputs and gives an output current proportional to the product of the two. Typical applications include: multiply, divide, square, square root, phase detection, frequency doubling, balanced modulation/demodulation and electronic gain control. An internal circuit diagram is given below for those interested.

Values and Limitations

1 For best temperature coefficient R1 (pin 1 to 0V) should be 16k(we used 15k as it is easier to obtain). This sets the value of all the current sources inside the IC (I1 = 8/R1)
2 The value of Rx (pin 11 to pin 12) should be ⩾3x peak input voltage(X) expressed in k ohms.
3 The value of Ry (pin 7 to pin 8) should be ⩾6x peak input voltage(Y) expressed in k ohms
4 Choose the scaling factor required ie Vout = K.Vx.Vy
5 Load resistance (pin 14 to 0V) can be calculated by RL=(K.Rx.Ry.I1)/2
6 If RL is connected between pin 14 and 0V without an inverting amp. the frequency response is limited by the output capacitance of 10pF.
7 For best temperature coefficient the load between pins 2 and 4 should be 8.6k.

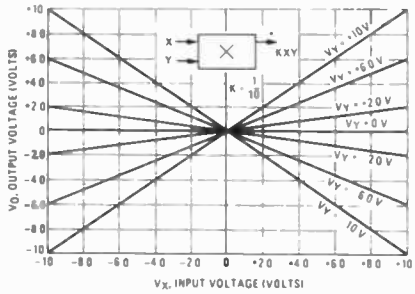


Fig. 6. Transfer characteristics of the IC.

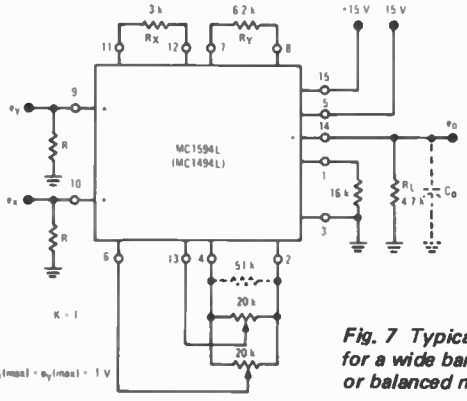


Fig. 7 Typical connections for a wide band multiplier or balanced modulator.

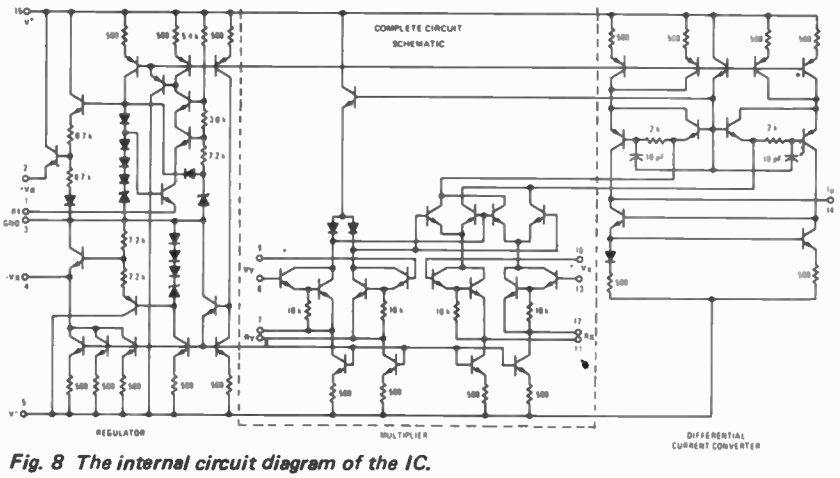


Fig. 8 The internal circuit diagram of the IC.

Fig. 9 Typical connection of a low frequency multiplier, For a squaring circuit simply parallel the two inputs. In this case pin 6 can be connected to 0V and P1 delated.

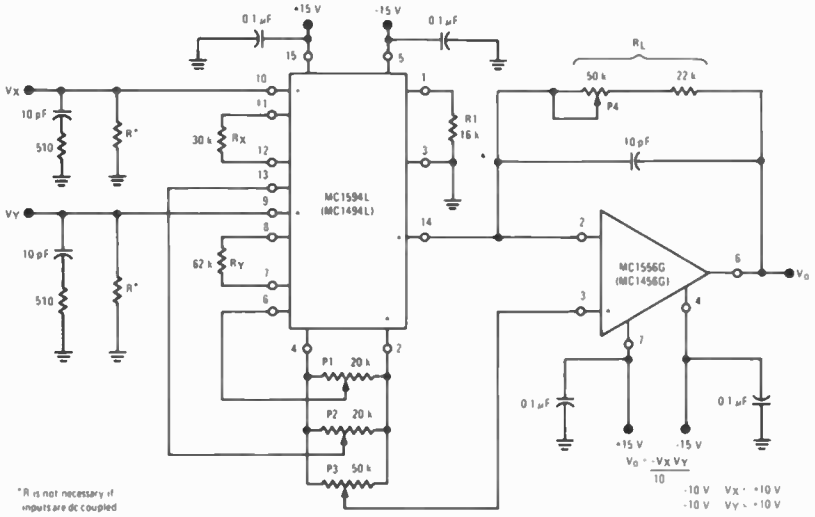
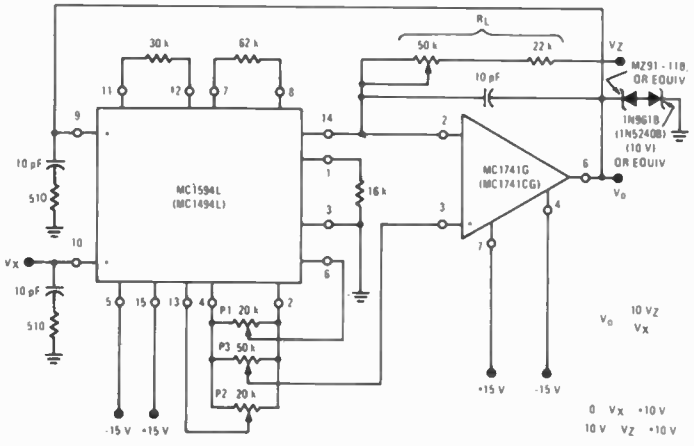
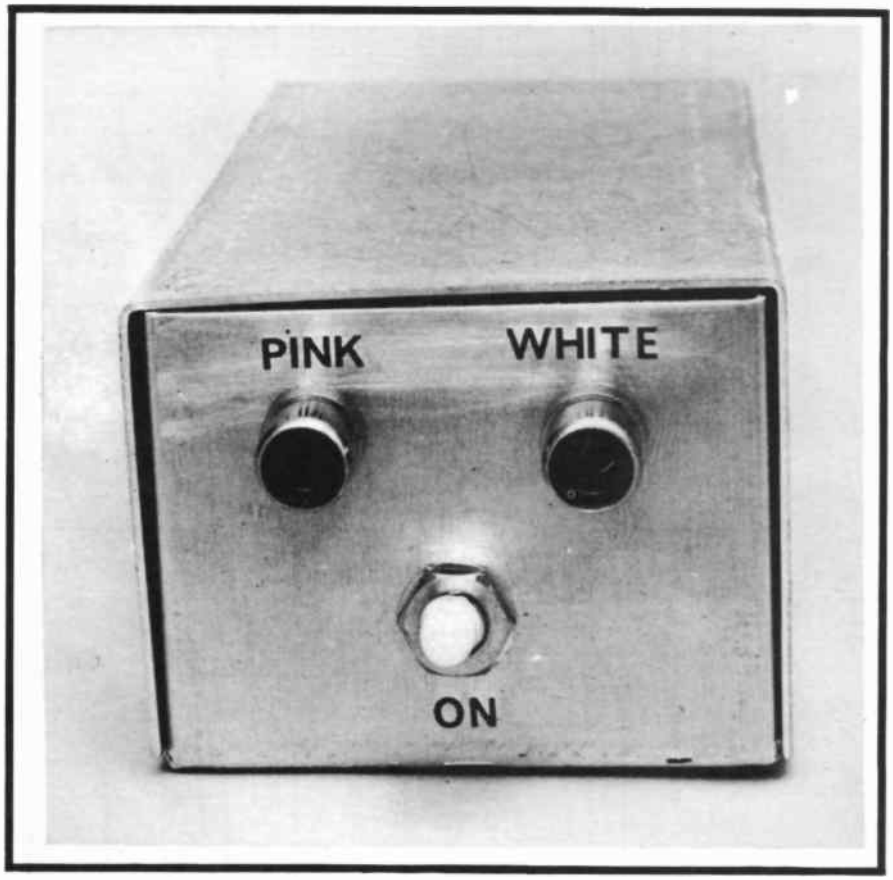


Fig. 10 Typical connection of a divide circuit. For the square root joins pin 9 and 10. Like the squaring circuits pin 6 can be . connected to 0V and P1 delated.



World Radio History

PROJECT 441 AUDIO NOISE GENERATOR



Simple circuit generates both white and pink noise.

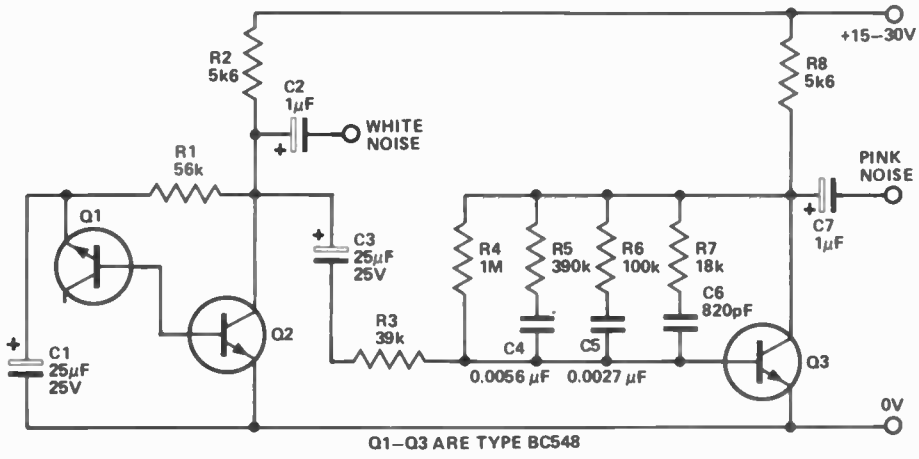


Fig. 1. Circuit diagram of the noise generator.

NOISE is generally an undesirable phenomena that degrades the performance of many measurement and instrumentation systems. It therefore seems strange that anyone should want to generate noise, but this is often the case.

Noise generators are often used to inject noise into radio-frequency amplifiers in order to evaluate their small signal performance. They are also used to test audio systems, and as random signal sources for wind-like effects in electronic music.

There are two commonly used noise source characteristics, 'pink' and 'white'. White noise is so called because it has equal noise energy in equal bandwidths over the total frequency range of interest. Thus, for example, a white noise source would have equal energy in the band 100 to 200 Hz to that in the band 5000 to 5100 Hz.

World Radio History

HOW IT WORKS – ETI 441

In the days when vacuum tubes were in common use the most commonly used form of noise generator was a vacuum-tube diode operated in the current saturation mode. Nowadays noise generators may be very complex indeed. Highly complex digital generators which produce psuedo-random digital noise may cost many thousands of dollars. An example of a simpler type of digital noise source may be found in our synthesizer design (see International Music Synthesizer 4600 ETI December 1973). However for audio work of a general nature the most commonly used, and the simplest, method is to use a zener diode as a noise generator.

Transistor Q1 is in fact used as a zener diode. The normal base-emitter junction is reverse-biased and goes into zener break-down at about 7 to 8 volts. The zener noise current from Q1 flows into the base of Q2 such that an output of about 150 millivolts of white noise is available.

The 'zener', besides being the noise source, also biases Q2 correctly, and the noise output of Q2 is fed directly to the White Noise output.

To convert the white noise to pink a filter is required which provides a 3 dB cut per octave as the frequency increases. A conventional RC network is not suitable as a single RC stage gives a cut of 6 dB per octave. Hence a special network of Rs and Cs is required in order to approximate the 3 dB-per-octave slope required. Since such a filter attenuates the noise considerably an amplifier is used to restore the output level. Transistor Q3 is this amplifier and the pink noise filter is connected as a feedback network between collector and base in order to obtain the required characteristic by controlling the gain-versus-frequency of the transistor. The output of transistor Q3 is thus the pink-noise required and is fed to the relevant output socket.

If white noise is filtered or modified in any way it is referred to as coloured noise or, often more specifically, as 'pink' or 'grey' noise. The term pink noise should be restricted to the noise characteristic that has equal energy per percentage change in bandwidth. For example with true pink noise the energy between 100 Hz and 200 Hz should equal that between 5000 Hz and 10 000 Hz (100% change in both cases).

Pink noise therefore appears to have more bass content than does white noise, and it appears to the ear to have a more uniform output level in audio testing. To change white noise to pink noise a filter is required that reduces the output level by 3 dB per octave (10 dB per decade) as the frequency is increased. The ETI 441 Noise Generator is designed to provide both white and pink noise as required.

PARTS LIST – ETI 441

R1	Resistor	56k	½W	5%
R2	"	5k6	½W	5%
R3	"	39k	½W	5%
R4	"	1M	½W	5%
R5	"	390k	½W	5%
R6	"	100k	½W	5%
R7	"	18k	½W	5%
R8	"	5k6	½W	5%
C1	Capacitor	25µF	25V	electro
C2	"	1µF	25V	electro
C3	"	25µF	25V	electro
C4	"	0.0056µF		polyester
C5	"	0.0027µF		polyester
C6	"	820pF		ceramic
C7	"	1µF	25V	electro

Q1-Q3 Transistor BC548, BC108 or similar
PC board ETI 441
CASE
BATTERIES
OUTPUT SOCKETS

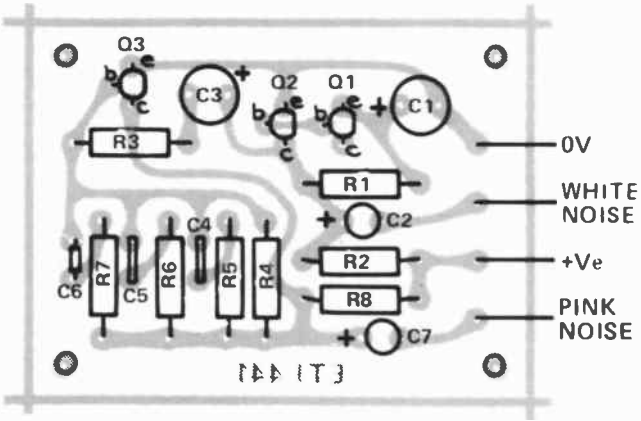
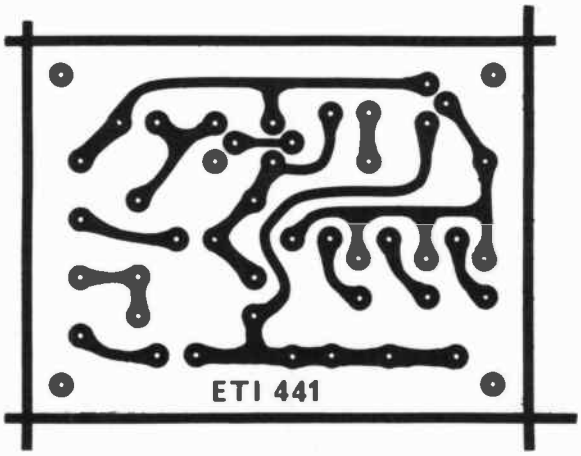


Fig. 2. Component overlay.



Printed circuit layout. Full size 67 x 49 mm.

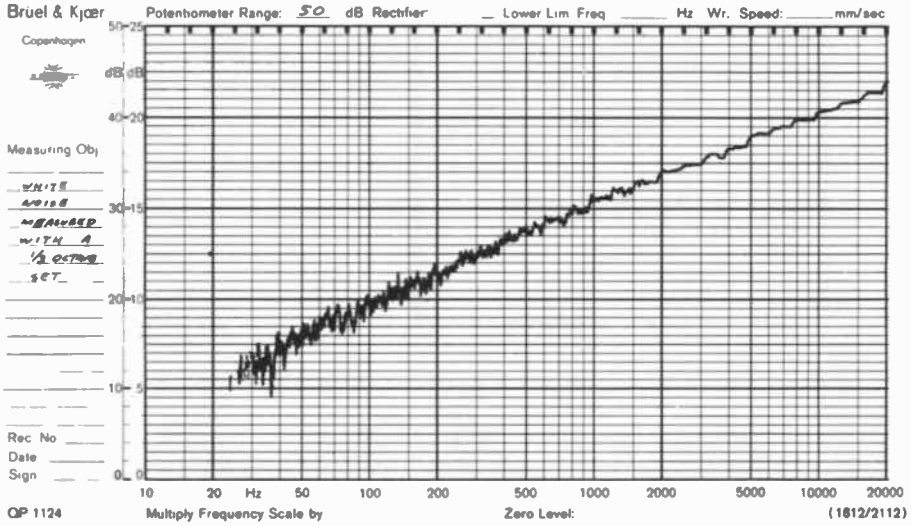
CONSTRUCTION

Construction is relatively simple and almost any of the common methods, such as Veroboard or Matrix board, may be used if desired. For neatness and ease of assembly it is hard to beat a proper printed-circuit board and for this reason we have provided details of a suitable board.

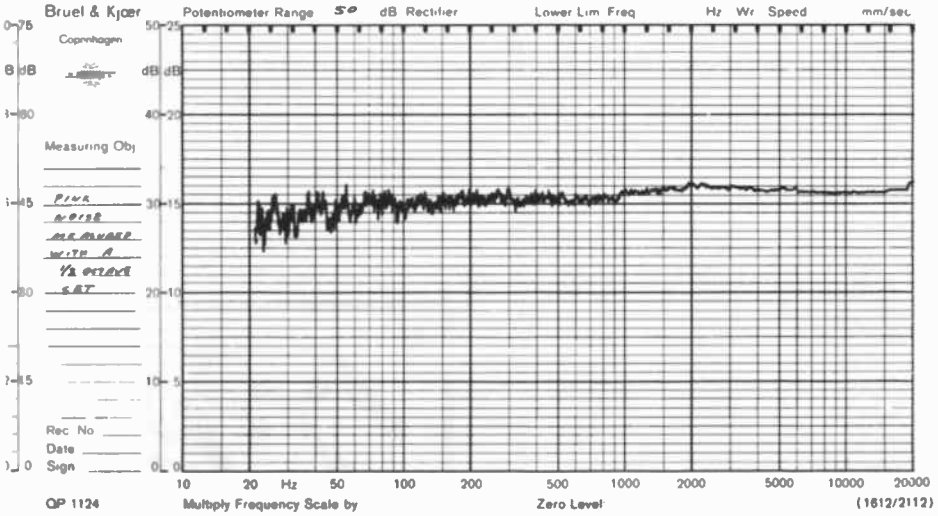
Almost any type of NPN transistor will do for the generator provided that the one used for Q3 has a gain of 100 or more. If BC548 type are used watch out for the two different pin connections used by different manufacturers.

For use as a separate instrument in general experimentation the unit will need to be powered by a pair of nine-volt batteries. However if the unit is to be built into some other piece of equipment, as is often the case, any supply within the equipment which has an output of between 15 and 30 volts dc will be suitable.

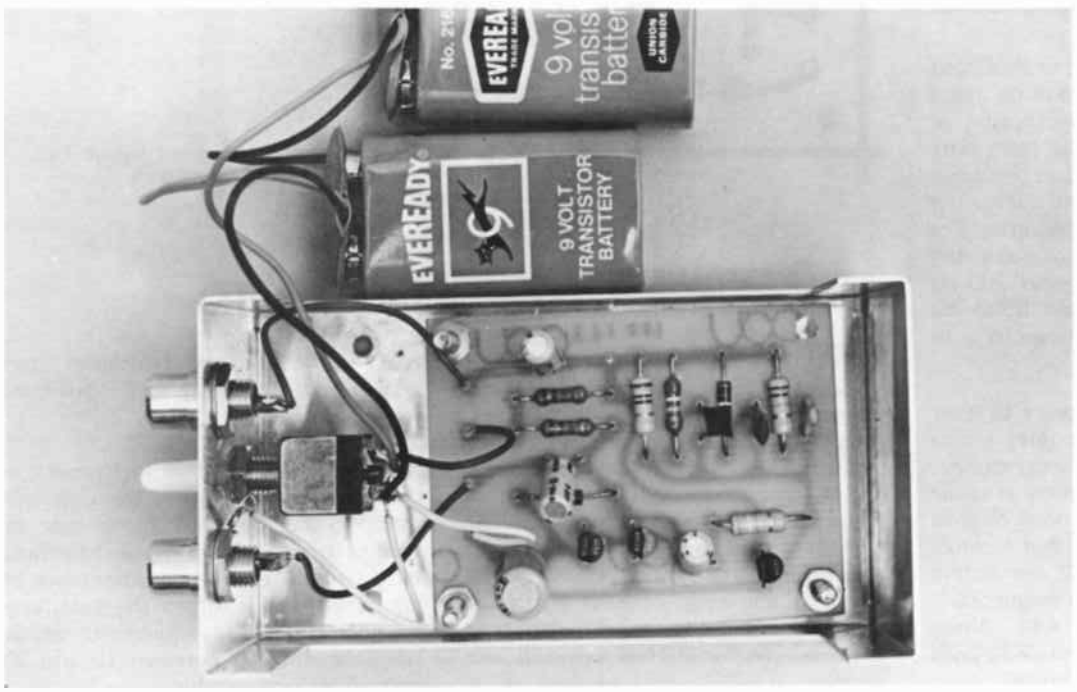
World Radio History



Amplitude of white noise versus frequency as measured with a one-third octave filter set.



Amplitude of pink noise versus frequency as measured with a one-third octave filter set.



Internal layout of the generator.

World Radio History

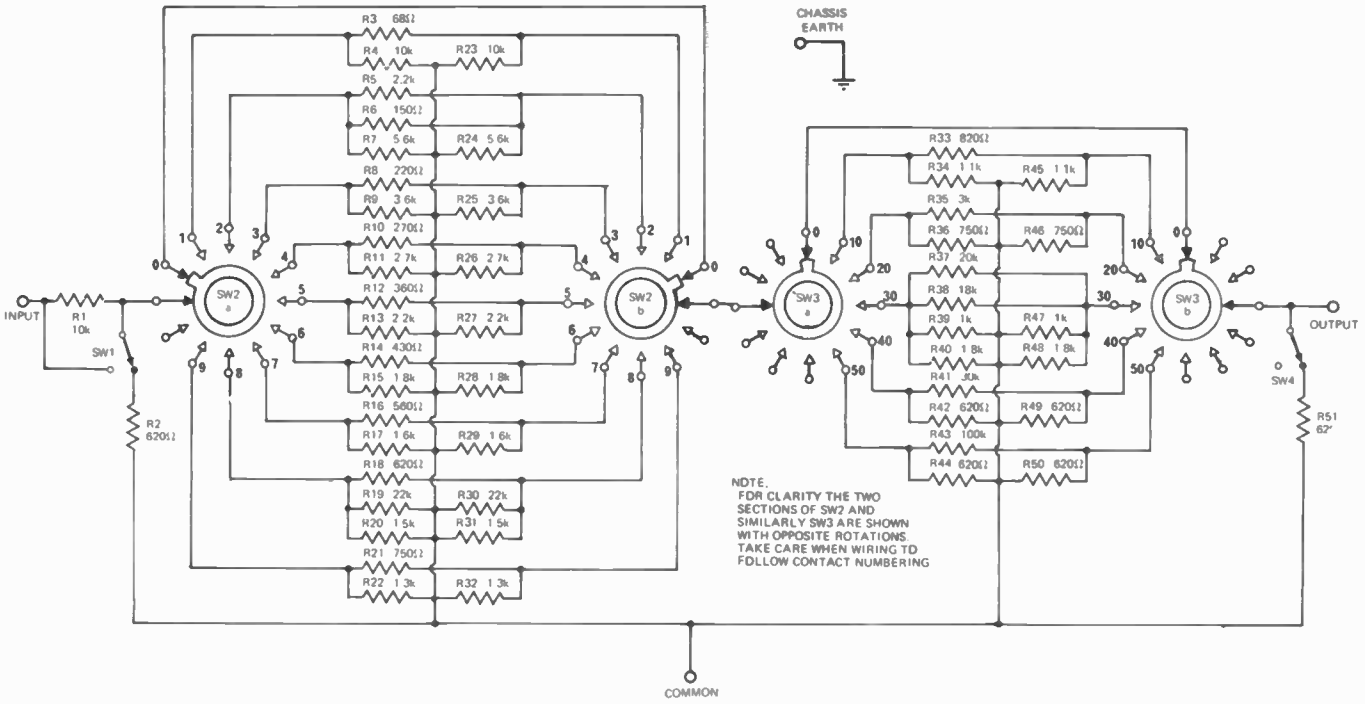


Fig. 1. Circuit diagram of the attenuator.

This useful audio attenuator project for the experimenter provides 0-59dB attenuation in one dB steps.

AUDIO ATTENUATOR

ACCURATE attenuators are required in a multitude of design, service, testing and measuring situations. These units are designed with varying degrees of accuracy and as many steps of attenuation as the designer feels necessary. They may be balanced or unbalanced and have whatever input and output impedances the designer requires.

There are three common types of attenuator configuration, Pi, T or L. The latter is mainly employed where the output impedance is not required to be constant.

PROJECT 112

We have chosen Pi type sections for our unit. We could have connected the various sections in tandem to form a ladder attenuator, but this would have made more complex rotary switches necessary. Instead, we chose to employ a separate section for each step of attenuation, making only simple rotary switches necessary.

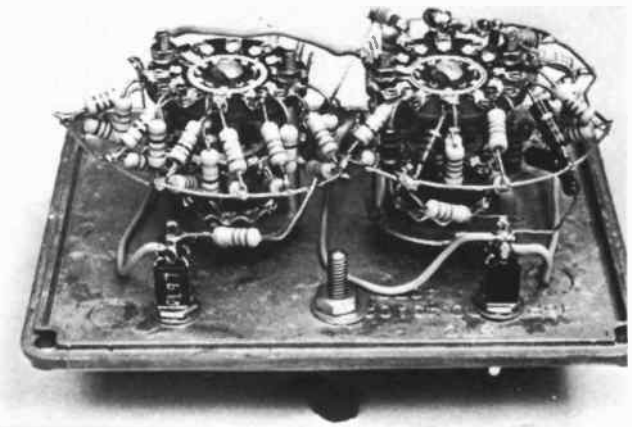
The input and output resistances of the unit remain relatively constant at 600 ohms over the full attenuation range. The input impedance can be changed to 10k by SW1 but an additional 30dB of attenuation is added. The output can also be terminated internally by SW4 when using a high impedance load such as a meter.

The maximum attenuation when the input and output resistances are set at 600 ohms is 59dB. There are ten 1dB steps from 0dB to 9dB, via a 10 position rotary switch, and a further six 10dB steps from 0dB to 50dB via a six position rotary switch, giving a

SPECIFICATION

Max attenuation	59dB
Resolution	1dB
Accuracy	±0.3dB
Frequency range	dc to 100kHz
Input impedance	600 Ω nominal
	10k switched (+30dB attenuation)
Output impedance	600 Ω nominal
Max input voltage	15 volt

Internal switched termination resistor for use with high impedance loads.



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PARTS LIST ETI 112

R1	Resistor	10k	2% ½W
R2	"	620Ω	" "
R3	"	68Ω	" "
R4	"	10k	" "
R5	"	2.2k	" "
R6	"	150Ω	" "
R7	"	5.6k	" "
R8	"	220Ω	" "
R9	"	3.6k	" "
R10	"	270Ω	" "
R11	"	2.7k	" "
R12	"	360Ω	" "
R13	"	2.2k	" "
R14	"	430Ω	" "
R15	"	1.8k	" "
R16	"	560Ω	" "
R17	"	1.6k	" "
R18	"	620Ω	" "
R19	"	22k	" "
R20	"	1.5k	" "
R21	"	750Ω	" "
R22	"	1.3k	" "
R23	"	10k	" "
R24	"	5.6k	" "
R25	"	3.6k	" "
R26	"	2.7k	" "
R27	"	2.2k	" "
R28	"	1.8k	" "
R29	"	1.6k	" "
R30	"	22k	" "
R31	"	1.5k	" "
R32	"	1.3k	" "
R33	"	820Ω	" "
R34	"	1.1k	" "
R35	"	3k	" "
R36	"	750Ω	" "
R37	"	20k	" "
R38	"	18k	" "
R39	"	1k	" "
R40	"	1.8k	" "
R41	"	30k	" "
R42	"	620Ω	" "
R43	"	100k	" "
R44	"	620Ω	" "
R45	"	1.1k	" "
R46	"	750Ω	" "
R47	"	1k	" "
R48	"	1.8k	" "
R49	"	620Ω	" "
R50	"	620Ω	" "
R51	"	620Ω	" "

SW1 Single pole change over minature toggle switch
SW2 2 pole 11 position rotary switch
SW3 2 pole 11 position rotary switch
SW4 Single pole change over minature toggle switch
Diecast box 4¾ x 3¾ x 2
4 Terminals type L1568/1S or similar
2 Knobs

total of 60 steps from 0dB to 59dB. This range of attenuation is adequate for most purposes. Although further sections could be added, noise becomes a limiting factor in a simple attenuator such as this.

CONSTRUCTION

It is advisable to employ separate wafers for each switch pole. If the type of switch that has two poles on one wafer is employed, there may be problems at the high frequency end due to stray capacitance. This would be evident as spikes on the leading edges of high frequency square waves.

The common rail for each switch is a length of 18 gauge tinned copper wire formed into a ring to allow termination of the shunt resistors (R4, R23, R7 and so on). The series resistors are connected directly between the relevant switch contacts. Layout of the unit may be seen by the accompanying photographs. ●

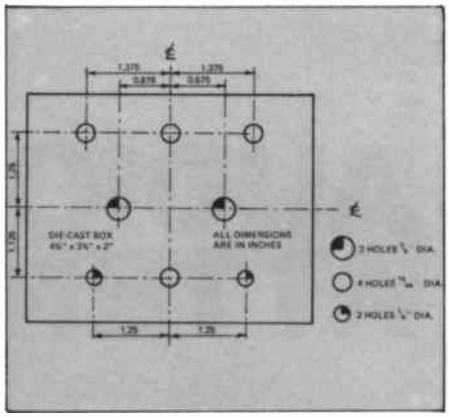

Fig. 2. Drilling details for the die cast box.

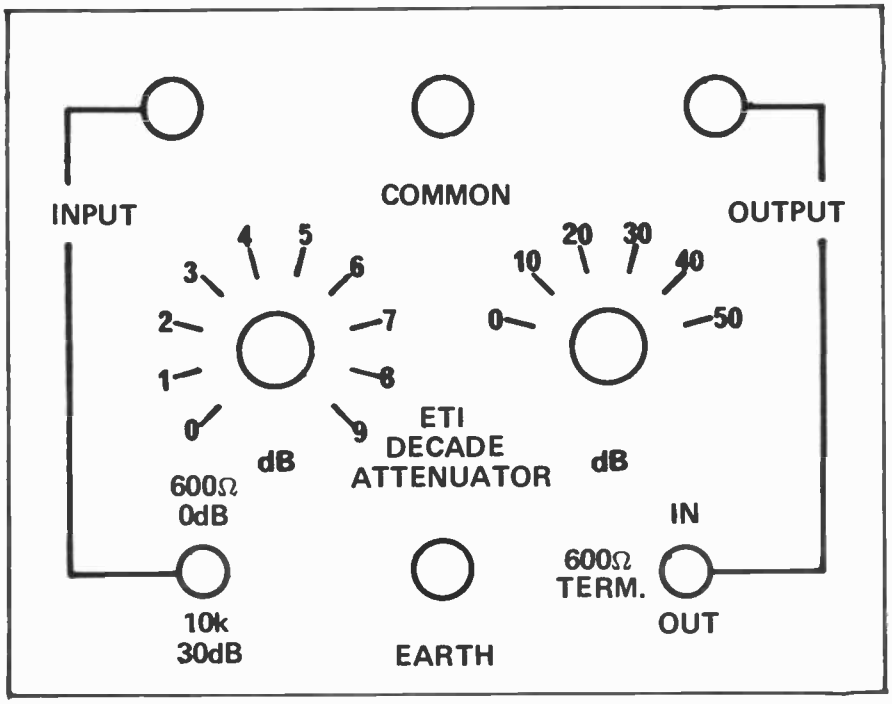

Fig. 3. Lettering and front panel artwork — full size.

World Radio History

Project 140

1 GHz FREQUENCY METER – TIMER

Pt. 1 Circuit Details

Lab-quality instrument offers superb performance and features at low cost.

OF THE VARIOUS QUANTITIES encountered in electronics (such as charge, voltage, current, frequency), perhaps the easiest to measure accurately is frequency. Various types of frequency-measuring equipment exist, ranging up from the simple absorption wavemeter (every ham should have one) to sophisticated multi-counter instruments which use microprocessors to calculate the measured frequency.

The earliest really accurate instruments were of the heterodyne type (such as the BC221), in which finely calibrated oscillator was tuned to zero-beat with the incoming signal. Many of these devices are still in use. In the late fifties and early sixties the first 'digital' counters appeared, based on Dekatron tubes, which are cunning decade counter and display valves.

Integrated circuits and LEDs have now made possible compact, portable counters that can be held in the palm of the hand, and these can easily be built by the hobbyist. What we haven't seen however, is a design for use at UHF, where CB and mobile radio are appearing or which offered versatile measurement of time or period.

With these thoughts in mind, we set out to do a design study, and came up with a lab-quality instrument which should be very reasonably priced. The design is based mainly on TTL with some CMOS and ECL. We rejected LSI MOS and CMOS devices for various reasons. Although this increases board size and power consumption, the gain in simplicity of layout and trouble-shooting, as well as leading zero suppression, is well worth-while.

SPECIFICATIONS ETI – 140

Modes of operation	**Frequency, period and time**
Range	
Frequency	10Hz – 50MHz
High frequency	50MHz – 1GHz *
Period	0.1μs – 10 sec.
Time	1μs – 100 sec.
Resolution	
Frequency	1Hz
High frequency	10Hz
Period	0.1μs
Time	1μs
Display	8 digit LED, leading edge blanking
Sensitivity	
Normal input	20mV
High frequency input	20mV
Time inputs	0V to +3V level shift
Input impedance	
Normal input	1Meg // 15pF
High frequency input	≈75 ohms
Time input	>10k
Maximum input voltages	
Normal input	70V ac,∓ 100V dc
High frequency input	200mV ac,∓ 50V dc
Timing inputs	∓100V dc
Crystal frequency	
nominal	4000kHz
actual	3999.995kHz
Stability and accuracy	
Frequency	Depends on crystal used and initial adjustment. Oven used keeps temperature within 2° C.
Period and time	approx −0.000125%

* The upper limit of the prescaler has not been checked due to the lack of a signal source but both the preamplifier (OM335) and the divider ICs are specified up to 1GHz.

World Radio History

Project 140

Design Feature

When considering this instrument initially we looked at ways to reduce both cost and component count of the unit. Our initial design of the counter section used TTL for the first two stages and CMOS for the rest. It then called for four 8 bit shift registers to take the information from the counters, latch it, and provide the multiplexing for the display. Multiplexing reduces the power consumption of the displays for the same light output and the total network would have saved 10-11 packages. However the PCB layout beat us unless a plated through board is used which would have cancelled any cost saving. The increased difficulty of fault-finding, even with fewer components, also weighed against this approach.

The counter in the LSD position has to operate at over 50 MHz. The only way to obtain this performance was to make our own divide by 10 using 74S74 dual D type flip flops as the 74LS90 is only specified to 32 MHz (although one sample we had worked at 60 MHz) and the 74S90 is no faster.

The network of 74S74's should give 60-70 MHz minimum clock rate.

Preamplifiers which can work from almost dc to 50 + MHz involving a Schmitt trigger always prove troublesome and this one was no exception. We originally dc coupled it throughout using matched FETs and a differential pair to give the correct level for the 9585 IC. This proved to have too much gain to be stable and the design shown here was the final result. Originally we used three diodes to limit the output voltage to +2v in the ECL-TTL translator but replacing it with a resistor-diode not only made it cheaper but increased the frequency response by 50% and improved stability.

Operation

The frequency and period modes are commonly known and do not require much explanation. The only extra control provided over the normal sensitivity control, is the dc shift. When measuring the frequency or period of a pulse waveform where the pulse is narrow in relation to the repetition rate, triggering problems can arise. This is due to noise pulses being counted as the average voltage is almost zero. However by using the dc shift the signal can be lifted above (or below) zero and the problem eliminated. For maximum sensitivity on normal ac signals the dc shift must be adjusted back to zero.

With the time mode intervals from 1 μs to 100 sec can be measured using pulses or level changes, into the respective sockets. A voltage change from 0V to 3V (or +3V to 0V) is all that is necessary although up to ∓ 100V can be used. For accurate timing the pulse should have a rise time of less than 1 μs. For measuring single pulses, both inputs can be paralleled and starting and finishing on opposite edges. If it is a repetitive pulse chain the unit will time the first pulse after the release of the reset button.

Calibration and Testing

To calibrate the unit a known frequency is needed so that CV1 can be adjusted to give the correct reading. Alternatively a radio receiver can be used tuned to the PMG 12 MHz time transmission, VNG, and the 4 MHz crystal beat against it (take a wire from pin 11 of IC30, wrap it around the radio aerial and adjust for zero beat. This sets the crystal to exactly 4 MHz. However this is not the exact frequency needed (life wasn't meant...). Now feed the 4 MHz into the input and record the result. It should be about 3,999,995 Hz which is about 0.000125% low. Now measure the frequency of another crystal (*or extremely stable*) oscillator, record the reading and then adjust CV1 to give a reading 0.000125% higher (or whatever error your unit requires). As this low reading is due to the time required for the strobe-reset pulses it is independent of the crystal frequency and adjusting CV1 will not affect the reading when the counter is used to measure its own internal frequency.

Adjustment of the crystal trimmer should not be done until it is warm (allow 10 minutes) and the oven should be fixed into the chassis to prevent movement of the leads which can affect the frequency slightly. If CV1 does not have enough range the parallel capacitor should be varied.

The period mode should be checked for operation. With the time mode the display can be reset by the push button and timing can be started by shorting out the start socket and stopped with the stop socket. Starting and stopping can also be performed by switching the polarity switches from negative to positive edge triggering. It should not be possible to restart the counter before the display has been reset.

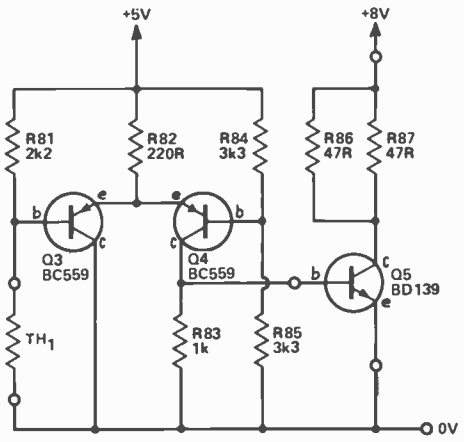

Fig. 1. The circuit diagram of the oven circuit

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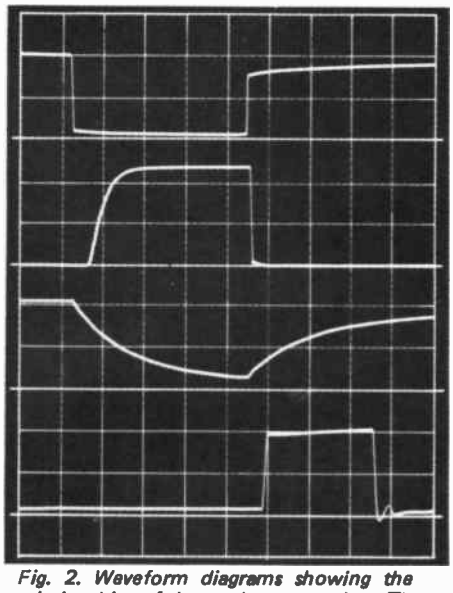

Fig. 2. Waveform diagrams showing the relationships of the strobe-reset pulses. They are, from the top down:
The output of IC37/1, pin 13
The 'strobe' pulse, i.e. the collector of Q2
The input to IC37/2, pin 10
The reset pulse on pin 5 of IC37/2
The vertical scale is 2 V/division while the horizontal is 200 ns /division. It can be seen that between the strobe pulse and the reset pulse there is a delay of about 50 ns.

The following pins are not shown on the circuit diagrams but are connected as shown below. Pins in the third * column are used as interconnections or are unused inputs terminated to some output.

	To +5V	To 0V	*
IC1	4,10,14	7	
IC2	4,10,14	7	
IC3	5	4,6,7,10	13
IC4	5	4,6,7,10	13
IC5	5	4,6,7,10	13
IC6	5	4,6,7,10	13
IC7	5	4,6,7,10	13
IC8	5	4,6,7,10	13
IC9	5	4,6,7,10	13
IC10	5	12	
IC11	5	12	
IC12	5	12	
IC13	5	12	
IC14	5	12	
IC15	5	12	
IC16	5	12	
IC17	5	12	
IC18	3,5,16	8	
IC19	3,16	8	
IC20	3,16	8	
IC21	3,16	8	
IC21	3,16	8	
IC22	3,16	8	
IC23	3,16	8	
IC24	3,16	8	
IC25	3,16	5,8	
IC26	14	7	8,9
IC27	5	2,3,6,7,10	
IC28	14	7	
IC29	14	7	
IC30	14	7	
IC31	2,4,6,7,10	11	
IC32	16	1,7,8,9,15	
IC33	16	1,8,9	1,2,3
IC34	14	7	
IC35	16	1,7,8,9	
IC36	14	7	
IC37	2,3,11,16	8	
IC38	14	7	1,2,5,6
IC39	14	7	
IC40	5,14	6,7,8	
IC41	14	7	
IC42	4,5	12	

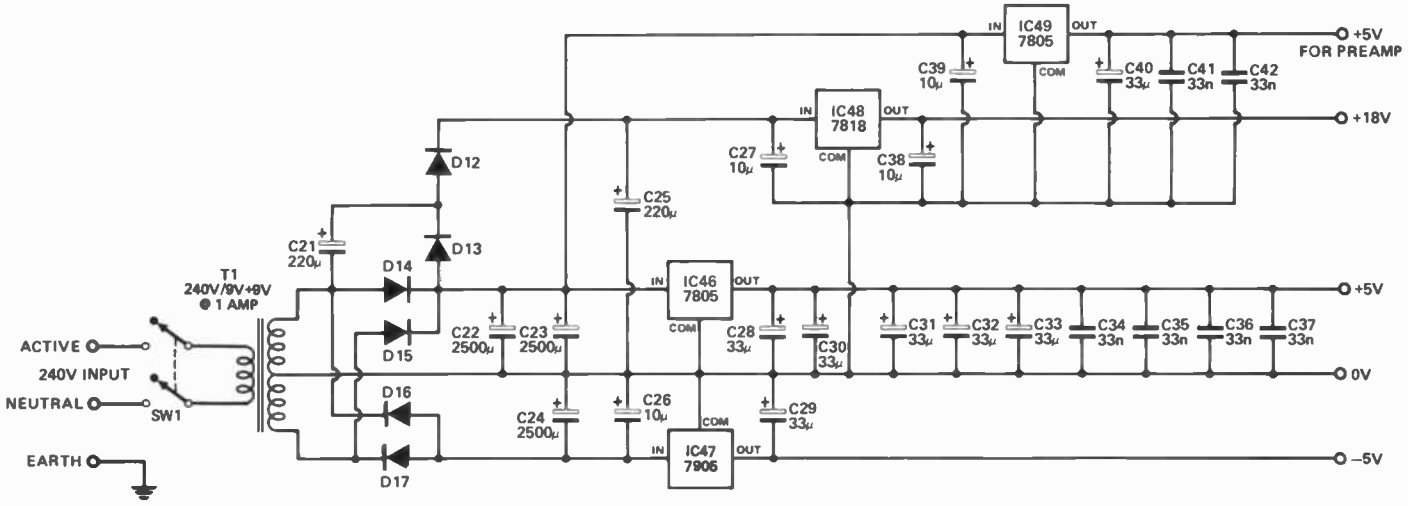

Fig. 3. The circuit diagram of the power supply

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1 GHz FREQUENCY METER – TIMER

HOW IT WORKS – ETI 140

The circuit is complex but can be separated into sections to make the explanation clearer:

A. Input preamplifier.
B. Prescaler.
C. Counter section.
D. Time base.
E. Frequency-period control logic.
F. Time measurement control logic.
G. Power supply.

Preamp

Transistors Q6, Q7 and Q8 form the high to low impedance unity gain buffer required to allow the one megohm input impedance. Diodes D5 and D6 prevent excessive input voltages damaging the unit.

Amplification is provided by IC42 which is an ECL triple differential line amplifier. Each stage has a gain of about seven giving a total voltage gain in IC42/1 and IC42/2 of around 50. The inputs of IC42/1 are biased to the internal reference voltage (pin 11) by R91 and R92 with the input signal being ac coupled via C10,11. The voltage on pin 16 can be dc shifted to allow better triggering on pulse type inputs.

The third section of IC42 is used as a Schmitt trigger to ensure that the output is square and jitter free. As the outputs of ECL move only from about +3.3 V to +4 V (on a +5V supply), a translater is needed to drive the TTL logic which follows.

Transistors Q10 and Q12 are both constant current sources with Q12 providing about 18 mA (0.6 V across 33 ohms). As the base of Q10 can be either of two levels (3.3 V or 4 V) it supplies either 33 mA (1.1 V across 33 ohms) or 9 mA (0.3 V across 33 ohms). As the two current sources are in series the differential current must go somewhere if they are to remain constant current supplies! With 33 mA from Q10, the difference (15 mA) flows through R103 and D9 to give about +2 V on the output. When the current drops to 9 mA the clamp diodes in the 74S10 which follows the preamp clip the voltage at about -0.7 V. If these limits were not used the the two inputs Q9 and Q13 are used to disable one of the inputs. With both transistors off the prescaler output is disabled (it needs a pulldown resistor), leaving the normal input active. If the transistors are on the prescaler is operational but the dc shift on pin 16 of IC42 forces the output (pin 7) high, effectively disabling the input.

Counter Section

The counter section consists of eight decade counters, latches, decoders and the LED displays. Due to the symmetry of the network the centre four stages aren't shown on the circuit diagram.

Seven of the counter stages are the familiar 7490/7475/7447 combination (except that they are the LS versions) but the decade counter of the LSD (least significant digit), which has to work at over 50 MHz is made out of four D type flip-flops using a NOR gate to get the divide by ten function. Both the D type flip-flops and the NOR gate have to be 'S' series TTL to give 50 MHz + operation (our prototype went over 100 MHz!).

All the counters can be reset by a '1' on the reset line and counting is advanced on the positive transition of the count input. With the latches, if the strobe line is high ('1'), whatever data is presented to it by the counter will be transferred to the decoders. When the strobe line goes to a '0' the data present at that time will be stored and displayed with the information from the counters no longer affecting the display.

Due to the interconnection between the decoder IC's the leading zeros will be blanked, leaving only the right hand digit on with no input signal. To reduce the load on the 5V regulator the displays are supplied from the unregulated supply.

Timebase

The timebase is a 4 MHz crystal with IC30/1 and IC31/2 providing the necessary amplifier to make an oscillator. The frequency is adjustable by CV1. For critical applications an oven can be used, stop dividing (this is used in the time mode). This 1 MHz output is then divided to 10 kHz by IC32 (dual decade counter) and then to 100 Hz or 62.5 Hz by IC33. This IC is a dual divide by 16 counter with the AND gate IC34/1 resetting the first half (IC33/1) upon reaching decimal 10 and IC34/2 and IC34/3 resetting the second half to zero at ten if the control input to pin 13 of IC34 is high. If it is low the reset pulse is disabled and the counter will divide by its normal 16. This change in division ratio is necessary as the prescaler divides by 16 and not 10. A final division by 100 is done by IC37 to give the final timebase periods of 1 s and 1.6 s.

Frequency-Period control logic.

In the frequency mode the output of the preamp is coupled to the count input of the display section via IC28/1 and IC28/3. These need to be 74S10 (not LS) to handle the frequencies involved. The 1 sec (or 1.6 sec) time base is coupled to the monostable IC37/1 via IC36/1 and IC36/3 and is therefore triggered every one second generating a pulse 800ns wide. This is used for the strobe pulse (open and close the latches every one second). This output also disables counting during this period to eliminate any error due to the latch closing while a pulse is still rippling through the decade counters.

The output of this mono has to be buffered by Q2 as the input of the latches is equal to 32 LS TTL loads (about 15mA). This transistor causes a propagation delay of 100 ns on the leading edge and 50 ns on the trailing edge. After a delay at about 80 ns (which is to compensate for the 50 ns propagation delay of Q2) the second monostable IC37/2 is triggered giving a 250 ns wide pulse. This is the reset pulse. The process of frequency measurement is therefore to reset the counters, clock the counters at the input frequency, after 1 sec open and close the latches which displays the number reached by the counters, then immediately reset the counters and start the process all over again.

In the period mode the 1 MHz output totally wrong result. Because of this we use the RS flip flop IC38 which is set by the strobe pulse, stopping any further pulses, and reset by the 'C' output of IC35/2. This IC (IC35/2) is reset by the strobe pulse and the 'C' output does not occur for 400 ms giving a maximum reading rate of 2.5 per second. The reset pulse is not involved in this process and occurs every 10 clock pulses of the input.

Time Measurement

Separate inputs are used for time measurement with both start and stop inputs available. These inputs are buffered by IC39 with both true and complementary outputs available.

Timing is done by coupling the 1MHz output to the count input (via IC28/2, IC28/3 as per period mode), holding the latches open so the counter information is always displayed and controlling the divide by 4 (IC31) to stop and start the counting.

This control is performed by the D type flip flops IC40/1 and IC40/2, after being gated by IC41/3 and IC41/4. If the Q output of IC40/1 is a '1' and the $\overline{Q}$ output of IC40/2 is a '1', IC31 will be enabled. When the reset button is pressed IC40/1 is set to a '0' on Q, and IC40/2 to a '1' on $\overline{Q}$, disabling IC31. This also puts a high on the 'A' input of the reset monostable IC37/2. When the button is released this causes a reset pulse to occur resetting the counters (and display) to zero.

The D input of IC40/1 is normally connected to a '1' and this is clocked into the Q output on the positive transition of the input to pin 3. When this occurs counting will start. This also puts a '1' on the D input of IC40/2 and if a positive transition occurs on pin 11 (clock) the Q will go to a '1' and the Q to '0', which will stop the counting. Triggering the stop input before the start will have no effect as the D input is a '0' and once toggled no further action will occur until reset by the pushbutton. Either positive or negative edge triggering can be selected allowing the width of a pulse to be measured by feeding it to both inputs and selecting the

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transistors would saturate, reducing the response to a few MHz.

Prescaler

For frequencies above 50 MHz, a prescaler is used with an amplifier IC43 providing about 26 dB gain to frequencies up to about 1 GHz and IC44 and IC45 each dividing the signal by four to give a total division by 16. To compensate for this odd division the timebase is changed from 1 sec to 1.6 sec when the prescaler is used.

As these dividers are ECL (what else at 1GHz!) a similar translater is used (Q11). To prevent interference between and this is controlled by Q3 and Q4. These transistors compare the voltages on their bases and control the drive to Q3, which, along with R86 and R87, is mounted on the crystal body to act as a heater. Also on the crystal body is the thermistor TH1 which provides the necessary feedback to Q3 to stabilize the temperature at about 70°C. The crystal is mounted in a polystyrene box to provide the thermal insulation required.

The output of the oscillator is buffered by IC30/3 before being divided by four by the JK flip flop IC31. If the JK inputs of IC31/1 are taken low the flip flop will from IC31 is gated into the count input via IC28/2 and IC28/3. The output of the preamp, after being divided by ten in IC27 then controls the strobe-reset monostables via IC36/2 and IC36/3. The result is that we count the number of one μs pulses in the time taken for 10 cycles of the input frequency. This gives the period of one cycle to 0.1 μs accuracy. Problems with flickering occur when updating a display more often than about 1/5 sec, especially 7 segment displays, as the eye cannot follow the change. It can be seen that if the display is alternating between 100 and 99 the result could appear as 188 which is a appropriate edge.

Power Supply

Four voltages are required for the unit: +5 volt for most of the logic, +8 volts unregulated for the displays (to save power disapation in the 5 volt regulator) +18 volts for the prescaler and -5 volt for the preamplifier. A separate +5 volt regulator is used for the preamplifier and prescaler to prevent any feed back via transients in the 0V line.

The regulators are standard 3 terminal regulators with the ∓8 volt supply simply fullwave rectified. The +26V for the 18V regulator is voltage tripled.

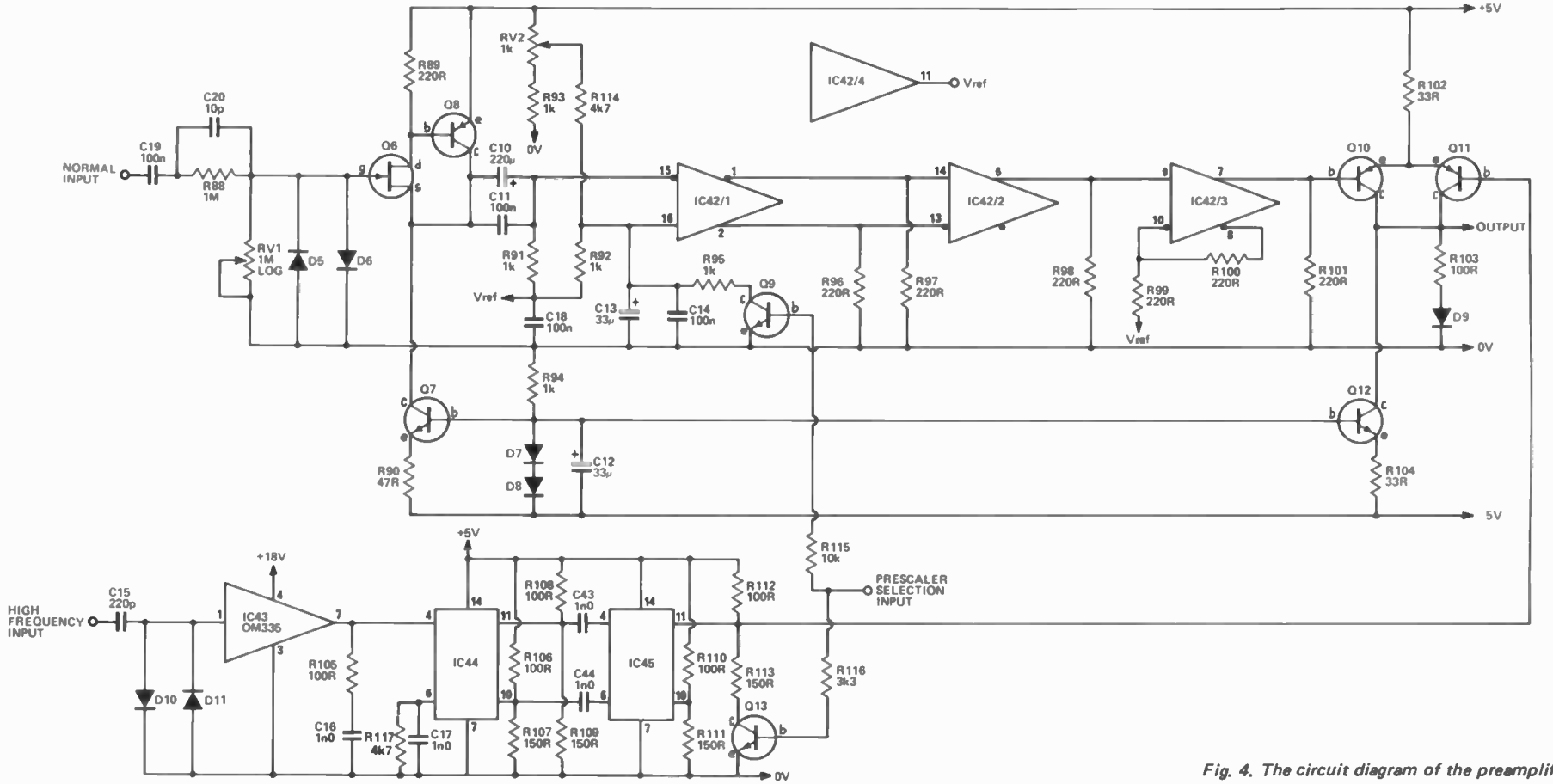

Fig. 4. The circuit diagram of the preamplifier.

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1 GHz FREQUENCY METER – TIMER

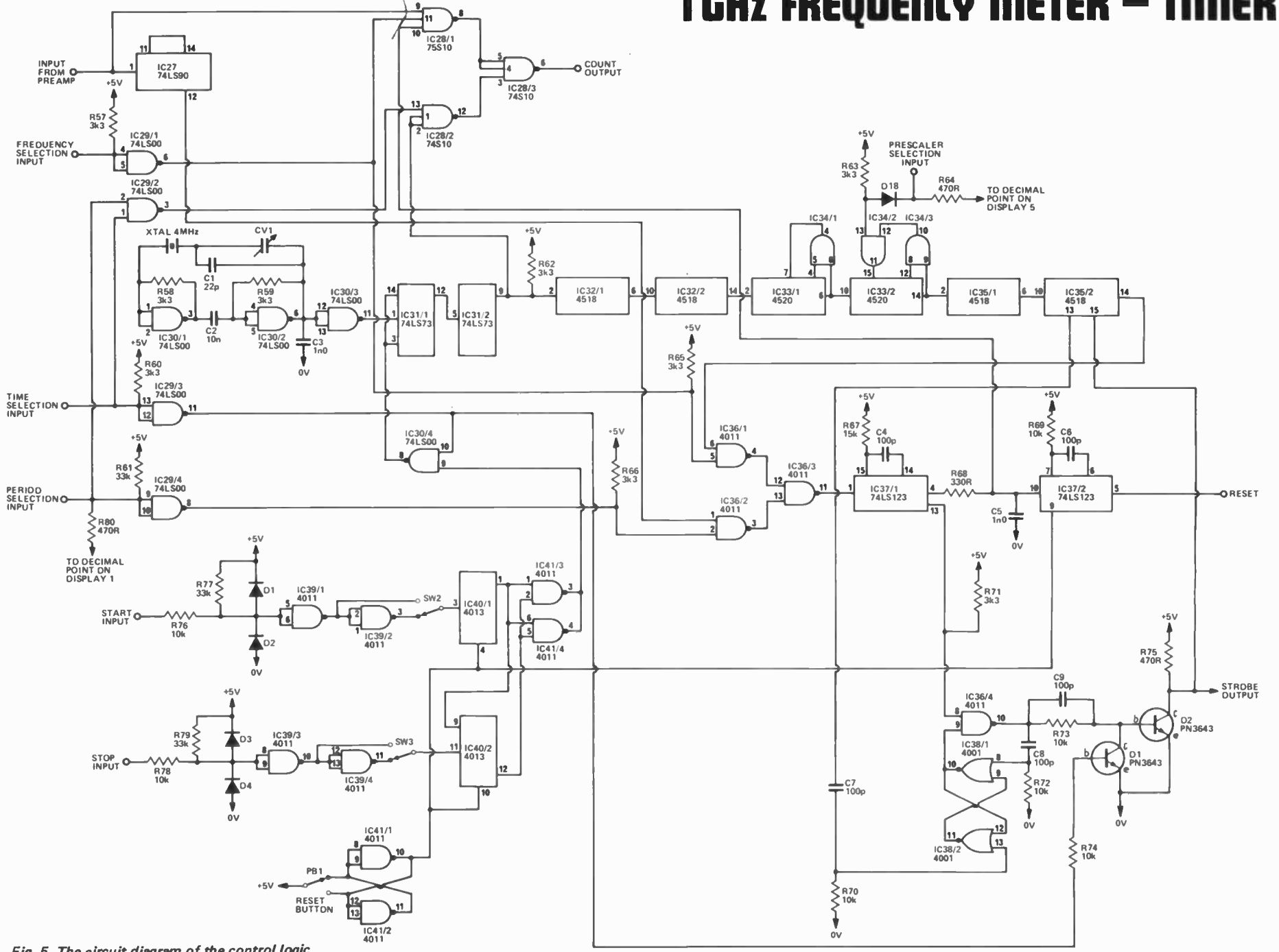

Fig. 5. The circuit diagram of the control logic

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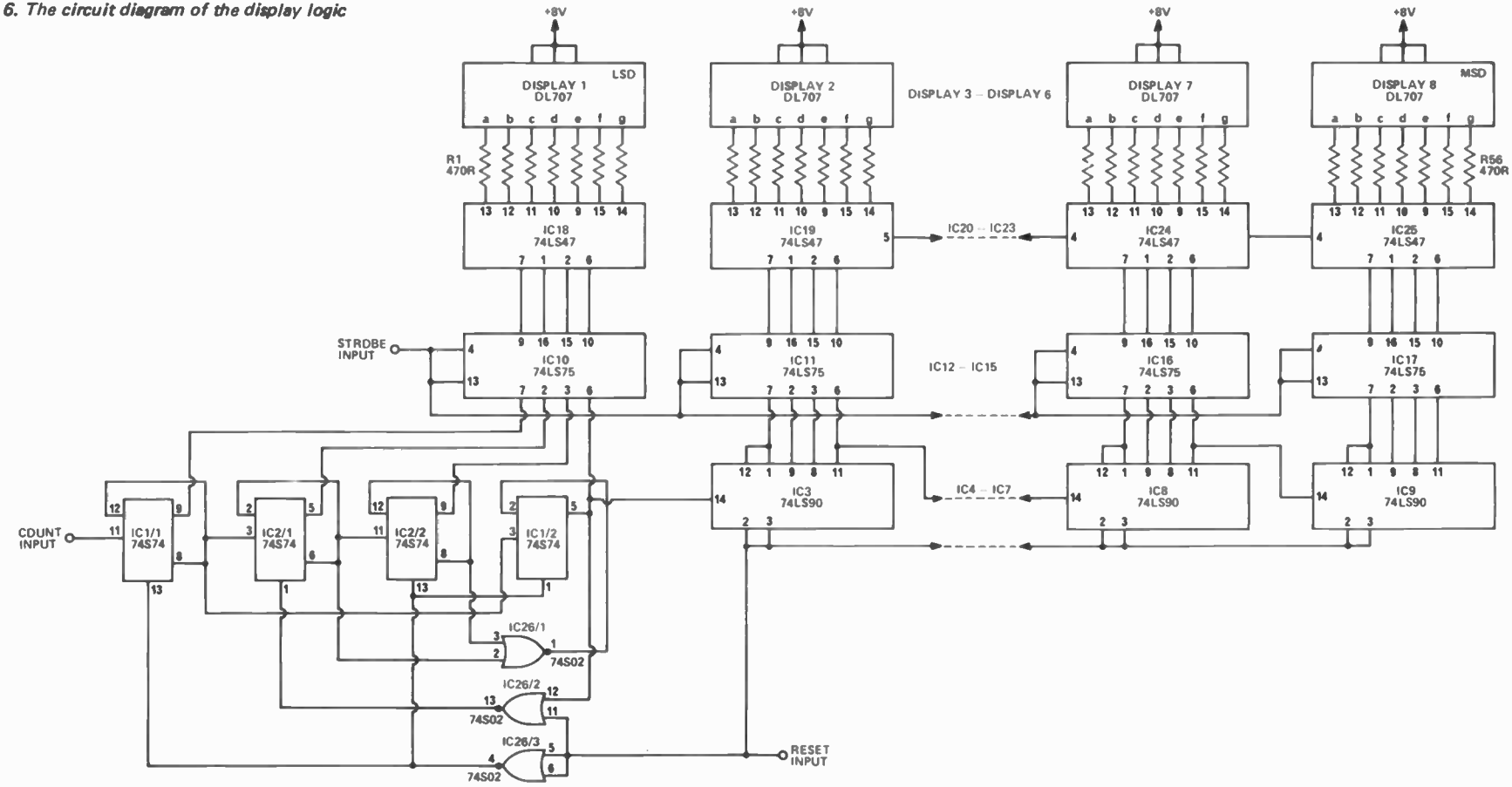
Fig. 6. The circuit diagram of the display logic



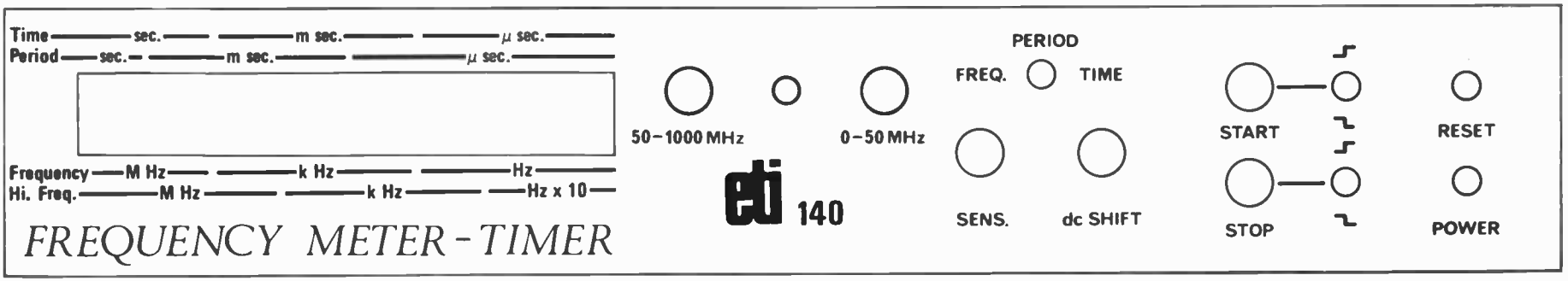


Fig. 7. The front panel artwork. Full size 320mm x 55mm

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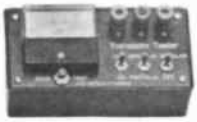

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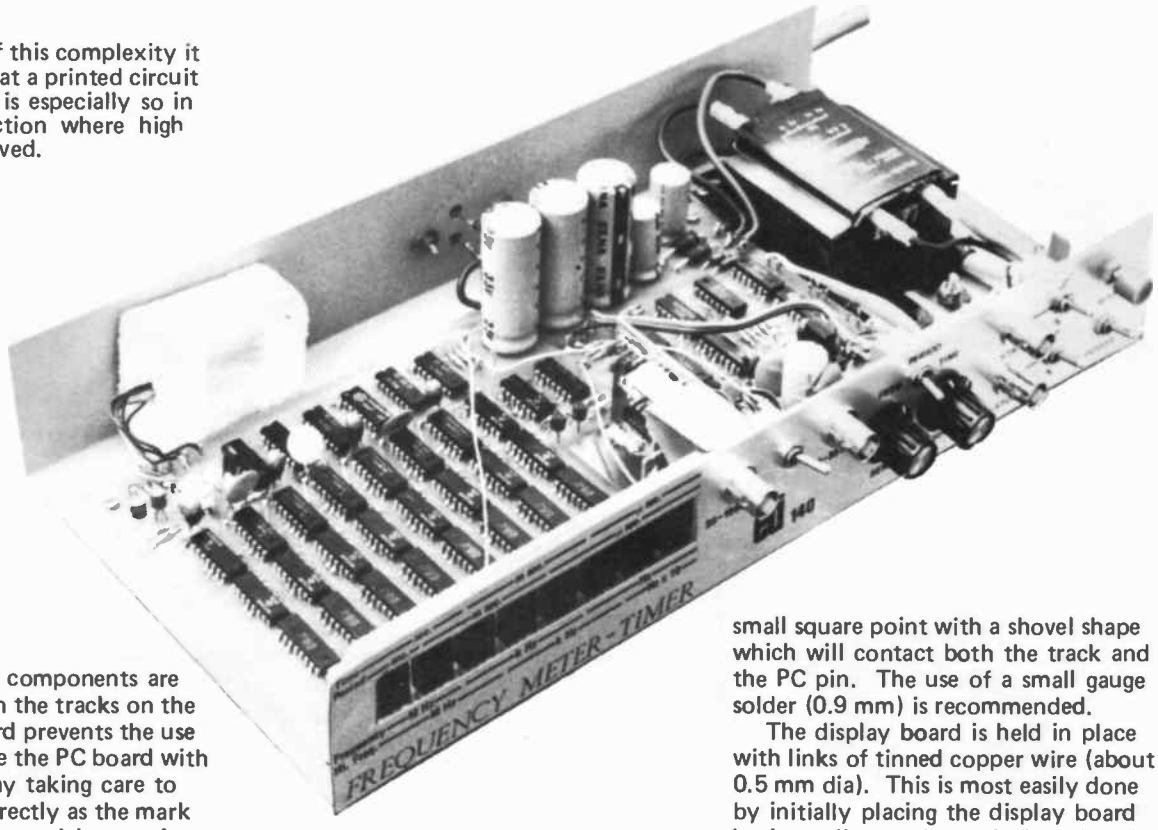
Project 140

1 GHz FREQUENCY METER – TIMER

Pt.2 Construction

Lab-quality instrument offers superb performance and features at low cost.

FOR A PROJECT of this complexity it is almost essential that a printed circuit board be used. This is especially so in the preamplifier section where high frequencies are involved.



The fact that the components are used as links between the tracks on the two sides of the board prevents the use of sockets. Assemble the PC board with the aid of the overlay taking care to orientate the ICs correctly as the mark is sometimes difficult to pick out. As the component leads are used as feed throughs it is not practical to build and test the unit in sections. Ensure that *all* pads on the top side of the board are soldered. Soldering the top surface is easiest if the tip of the iron is filed to a small square point with a shovel shape which will contact both the track and the PC pin. The use of a small gauge solder (0.9 mm) is recommended.

The display board is held in place with links of tinned copper wire (about 0.5 mm dia). This is most easily done by initially placing the display board horizontally on the main board and inserting loops of wire through the holes provided (see photo). When all the links are in place the board can be twisted into a vertical position and by pulling on the ends of the links the display board can be pulled down flush with the

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main board. It can now be soldered into place. Two additional resistors are needed per digit; the photo shows their position. The potentiometers are mounted on a small bracket (see Fig.20) before being soldered onto the main board.

The prescaler, if used, is also mounted in a similar way except that due to the small number of connections the links should be passed through the holes in the prescaler, bent flush with both sides and then mated with the main board. Solder the pads on the underside of the main board only at this stage. On the prescaler board there is a tin plate shield which should be soldered into position with a fillet of solder. Don't solder the top edge yet as capacitor C15 can only be fitted after the unit is in the chassis. Also note that the capacitors C43 and C44 are mounted on the rear of the PCB as shown in Fig. 15 along with R116.

The crystal is fitted into a polystyrene box (about 50 x 40 x 25 mm) with transistor Q5, R86, 87 and TH1 being glued onto the crystal body to act as a heater and sensor.

Before mounting the unit into the chassis assemble all the front panel components, also glueing the polarised plastic into position. Note that there is an earth lug under the prescaler input socket and the nut for the socket should be in the position shown in Fig. 8 as the board fits between the nut and the earth lug which is bent back along the surface of the board.

The unit should now be temporarily mounted into the chassis to locate the prescaler board in its correct position between the nut on the input socket and the earth lug. Fix it in this position by running a small fillet of solder between the two boards. When the unit is removed run the fillet of solder the full length (where there is copper!!) on both sides of the prescaler board.

Assemble the unit finally and wire it up as shown in the wiring diagram. The transformer can be mounted and wired along with the 5 V regulator. Insulation washers should be used with this regulator even though the case is at earth potential to prevent any problem of having two earth points (the other is the lug under the prescaler input socket).

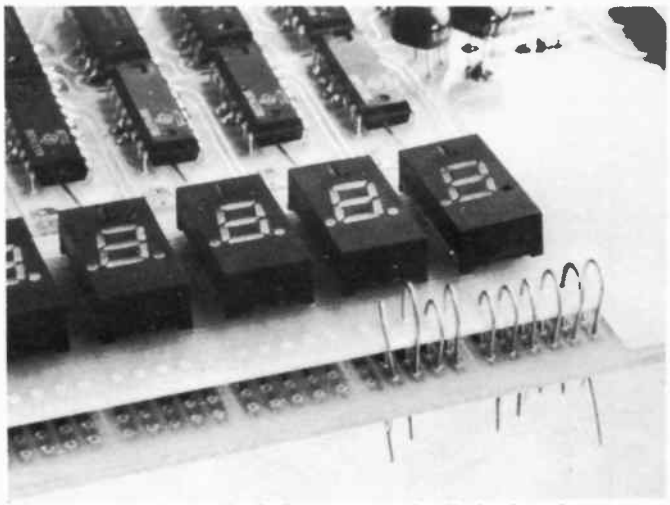
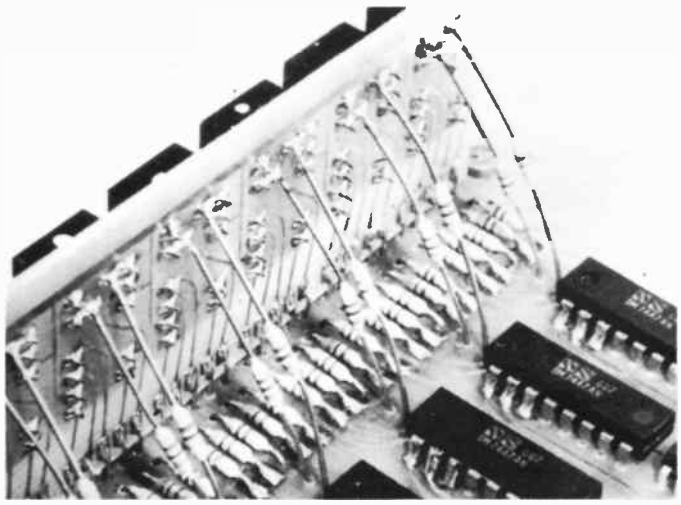
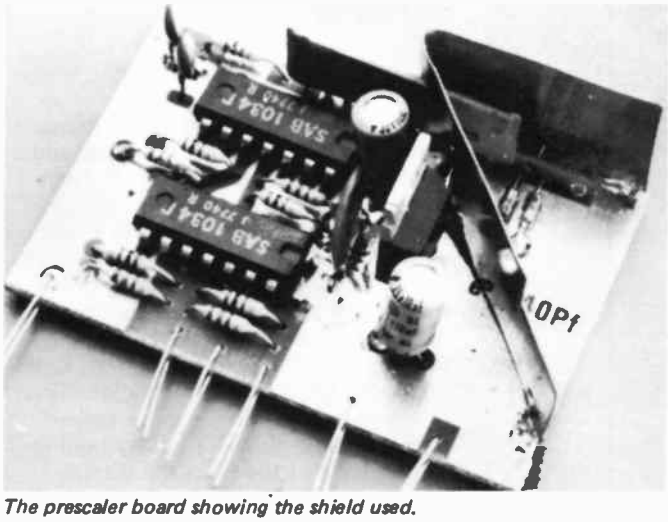


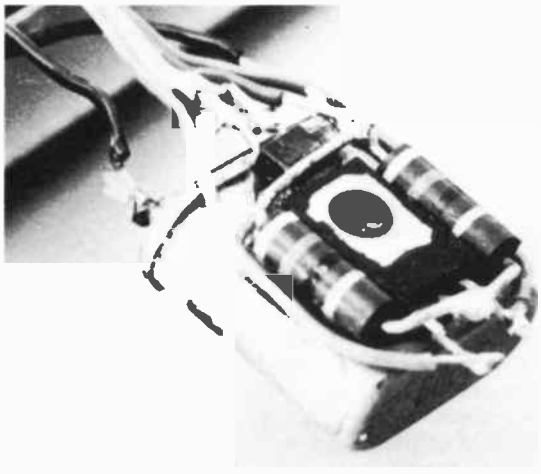
Photo showing the method of connecting the display board.



The position of the two additional resistors required per display is shown in this photograph.



The prescaler board showing the shield used.



The method of mounting the components on the crystal.

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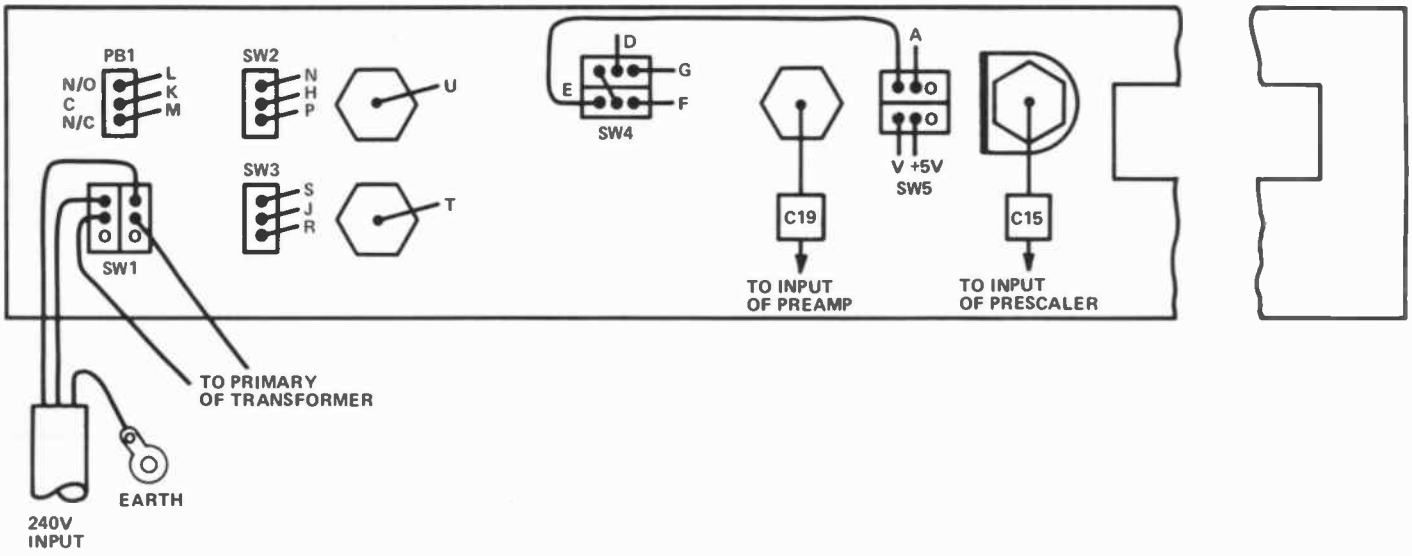

Fig. 8. Rear view of the front panel wiring.

ICs used in the prescaler.

Most of the ICs used in this project are standard TTL or CMOS and only the prescaler ICs are unusual. For this reason details of these ICs are given below.

OM335

This is a high frequency linear amplifier designed for instruments or TV amplifier.

Gain	27dB typ.
Freq. resp. ∓ 1dB	20–1000MHz
Input impedance	75ohm
Output impedance	75ohm
Power Supply	8–28V dc @ 35mA

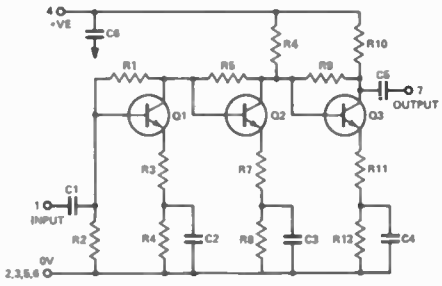

Fig. 9. Internal circuit diagram of the OM335.

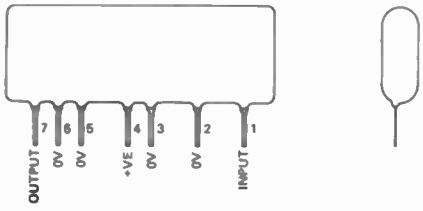

Fig. 10. Pin connections of the OM335.

SAB1048

This is a high frequency 4/1 divider (prescaler) and is designed to operate from a sinewave (50MHz min) or square wave (dc). The output is ECL compatable. The internal circuit - block diagram is given below. The differential inputs are internally biased and should be ac coupled. If only one input is used the other should be ac grounded.

Freq. range (sine wave)	50–1000MHz
Sensitivity	see graph
Power requirement	5.2V @ 53mA

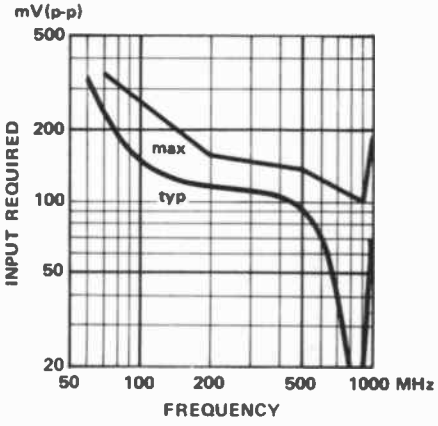

Fig. 12. Sensitivity of the SAB1048 with a sinewave input.

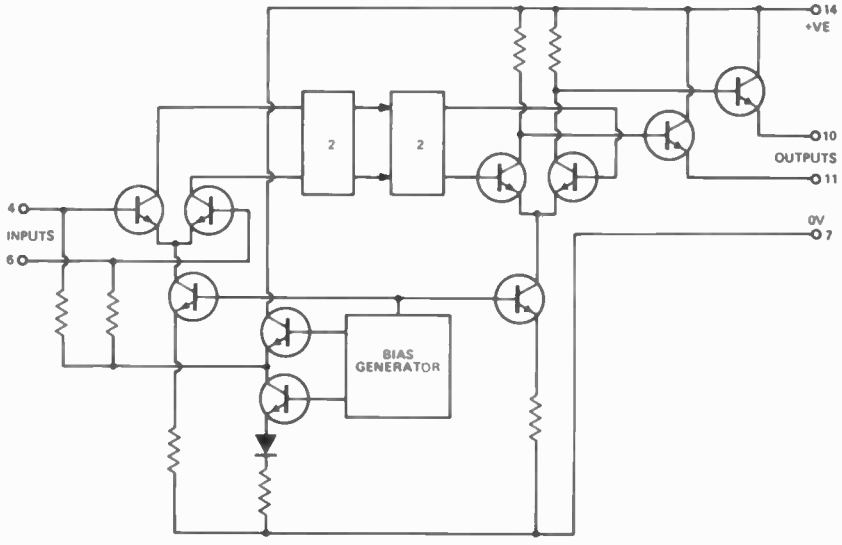

Fig. 11. Block diagram of the SAB1048.

World Radio History

1 GHz FREQUENCY METER – TIMER

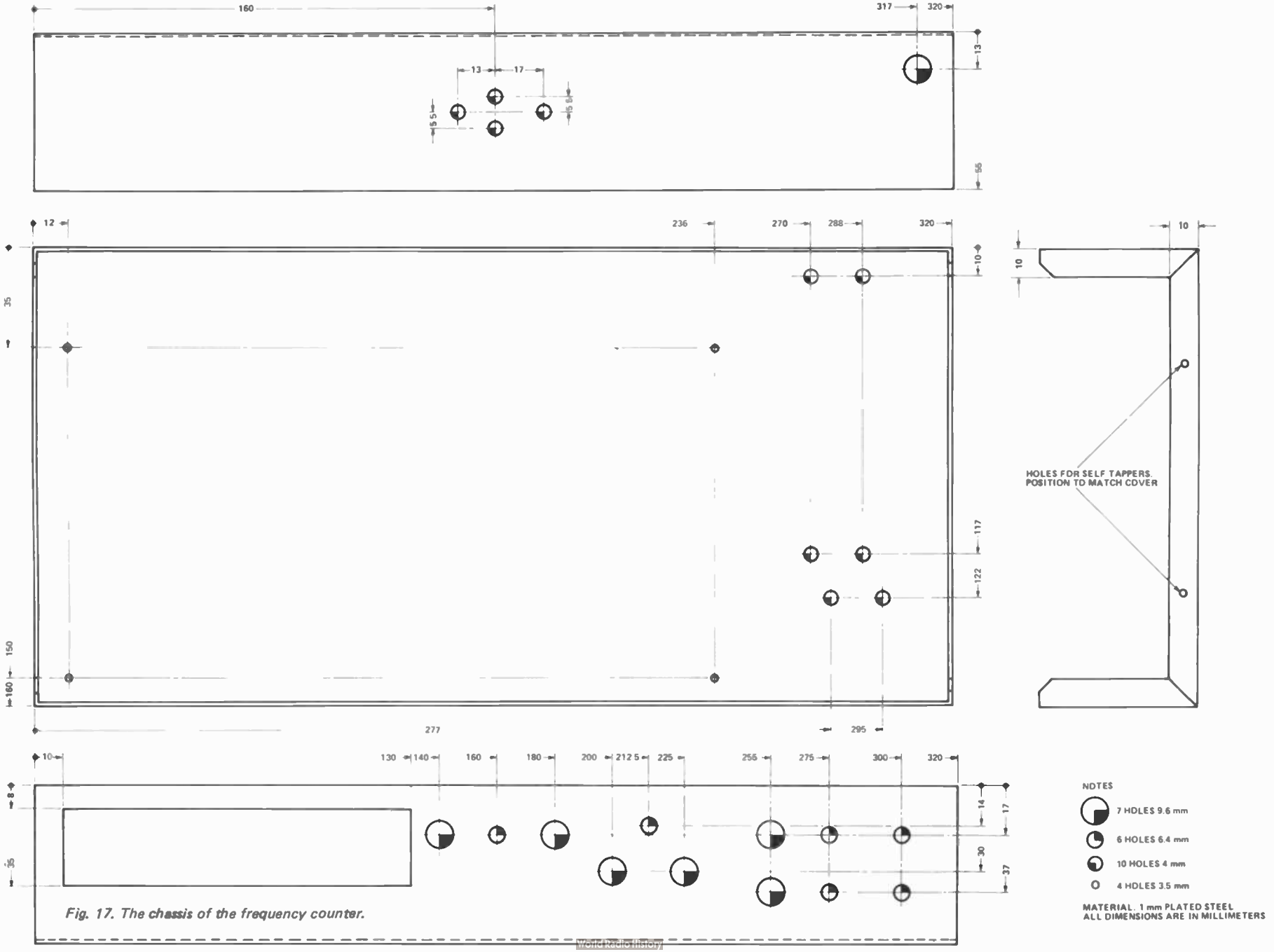

Fig. 17. The chassis of the frequency counter.

World Radio History

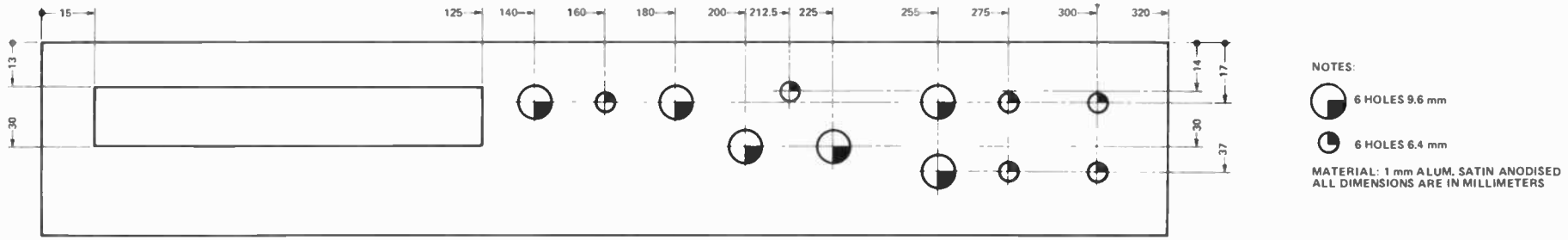

Fig. 18. The dimensions of the front panel.

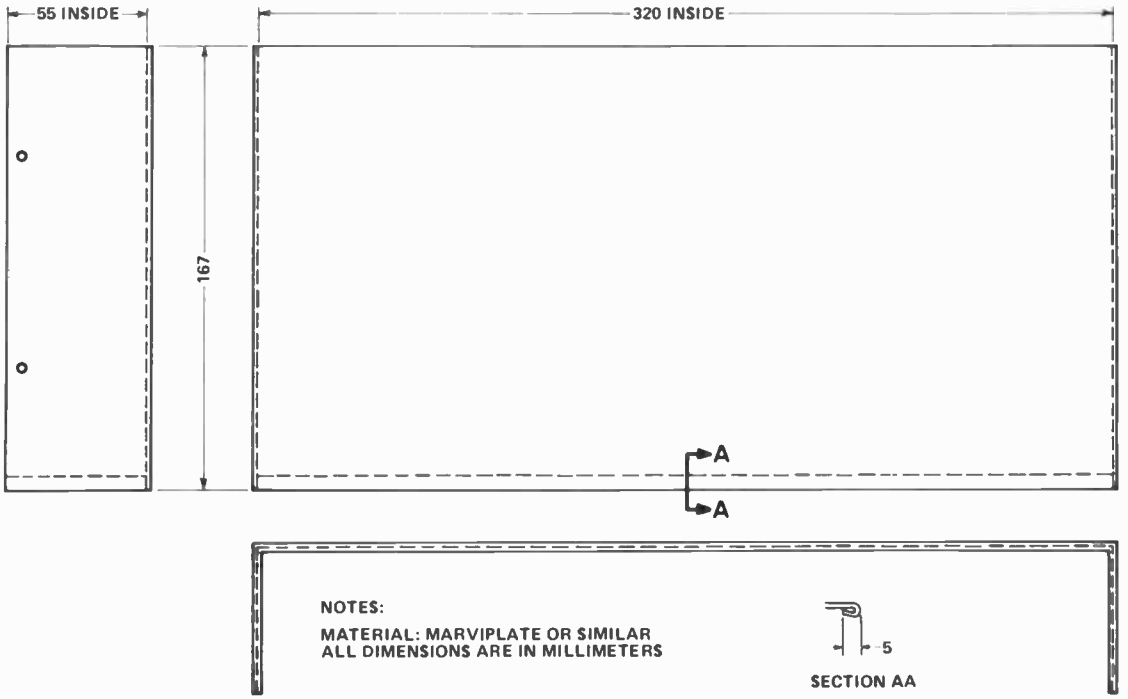

Fig. 19. The cover for the frequency counter.

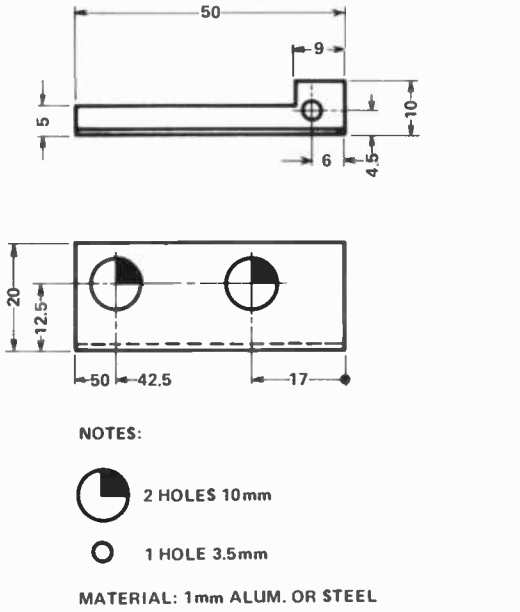

Fig. 20. The potentiometer mounting bracket.

World Radio History

1 GHz FREQUENCY METER – TIMER

PARTS LIST – ETI 140

Resistors all ¼W, 5% unless stated

R1-R56 . . . . 470R
R57-R60 . . . . 3k3
R61 . . . . . 33k
R62,63 . . . . 3k3
R64 . . . . . 470R
R65,66 . . . . 3k3
R67 . . . . . 15k
R68 . . . . . 330R
R69,70 . . . . 10k
R71 . . . . . 3k3
R72-R74 . . . . 10k
R75 . . . . . 470R
R76 . . . . . 10k
R77 . . . . . 33k
R78 . . . . . 10k
R79 . . . . . 33k
R80 . . . . . 470R
R81 . . . . . 2k2
R82 . . . . . 220R
R83 . . . . . 1k
R84,85 . . . . 3k3
R86,87 . . . . 47R ½W
R88 . . . . . 1M
R89 . . . . . 220R
R90 . . . . . 47R
R91-R95 . . . . 1k
R96-R101 . . . 220R
R102 . . . . . 33R
R103 . . . . . 100R
R104 . . . . . 33R
R105,106 . . . 100R
R107 . . . . . 150R
R108 . . . . . 100R
R109 . . . . . 150R
R110 . . . . . 100R
R111 . . . . . 150R
R112 . . . . . 100R
R113 . . . . . 150R
R114 . . . . . 4k7
R115 . . . . . 10k
R116 . . . . . 3k3
R117 . . . . . 4k7

Potentiometers

RV1 . . . . . 1M log PR16PC (Plessey)
RV2 . . . . . 1k lin "

Thermistor

TH1. . . . . Philips 2322 640 90004

Capacitors

C1. . . . . 22p NPO ceramic
C2. . . . . 10n polyester
C3. . . . . 1n0 "
C4. . . . . 100p ceramic
C5. . . . . 1n0 polyester
C6-C9. . . . . 100p ceramic
C10. . . . . 220µ 16V electro *
C11 . . . . . 100n disc ceramic
C12,13 . . . . 33µ 10V tantalum
C14 . . . . . 100n disc ceramic
C15 . . . . . 220p silver mica
C16,17 . . . . 1n0 disc ceramic
C18,19 . . . . 100n 100V disc
C20 . . . . . 10p 100V ceramic
C21 . . . . . 220µ 35V electro*
C22-C24 . . . . 2500µ 16V electro *
C25 . . . . . 220µ 35V electro *
C26 . . . . . 10µ 16V tantalum
C27 . . . . . 10µ 35V electro *
C28-C33 . . . . 33µ 10V tantalum
C34-C37 . . . . 33n disc ceramic
C38 . . . . . 10µ 35V electro *
C39 . . . . . 10µ 10V tantalum
C40 . . . . . 33µ 10V tantalum
C41,42 . . . . . 33n disc ceramic
C43,44 . . . . . 1n0 disc ceramic

* all electrolytic capacitors should be the single ended types.

Variable Capacitors

CV1. . . . . 2–10p trimmer

Semiconductors

IC1,2 . . . . . 74S74
IC3-IC9. . . . . 74LS90
IC10-IC17 . . . 74LS75
IC18-IC25 . . . 74LS47
IC26 . . . . . 74S02
IC27 . . . . . 74LS90
IC28 . . . . . 74S10
IC29,30 . . . . 74LS00
IC31 . . . . . 74LS73
IC32 . . . . . 4518 (CMOS)
IC33 . . . . . 4520 (CMOS)
IC34 . . . . . 4081 (CMOS)
IC35 . . . . . 4518 (CMOS)
IC36 . . . . . 4011 (CMOS)
IC37 . . . . . 74LS123
IC38 . . . . . 4001 (CMOS)
IC39 . . . . . 4011 (CMOS)
IC40 . . . . . 4013 (CMOS)
IC41 . . . . . 4011 (CMOS)
IC42 . . . . . 9582 (ECL)
IC43 . . . . . OM335
IC44.45 . . . . SAB1048P,SAB1034P
IC46 . . . . . 7805 (TO3 package)
IC47 . . . . . 7905 (500mA version)
IC48 . . . . . 7818 (500mA version)
IC49 . . . . . 7805 (500mA version)

Q1,2 . . . . . PN3643, 2N3643
Q3,4 . . . . . BC559
Q5 . . . . . BD139
Q6 . . . . . 2N5485
Q7 . . . . . PN3643, 2N3643
Q8 . . . . . PN3645, 2N3645
Q9 . . . . . PN3643, 2N3643
Q10,11 . . . . PN3645, 2N3645
Q12,13 . . . . PN3643, 2N3643

D1-D9 . . . . . 1N914
D10,11 . . . . . BAW62
D12,13 . . . . 1N4004
D14,15 . . . . 1N5404
D16-D18 . . . . 1N4004

Displays 1-8 . . DL707

Miscellaneous

PC board . . . . ETI 140A
PC board . . . . ETI 140D
PC board . . . . ETI 140P
Crystal . . . . . 4MHz, 30pF, 70°c
SW1. . . . . 7201 toggle switch
SW2,3 . . . . . 7101 toggle switch
SW4. . . . . 7211 toggle switch
SW5. . . . . 7201 toggle switch
PB1 . . . . . 8168 push button
Transformer . . 240V – 9V + 9V @ 1A PL18/20VA
Metalwork to suit
4 B&C sockets
3 core flex and plug
cable clamp
Piece of polarised plastic

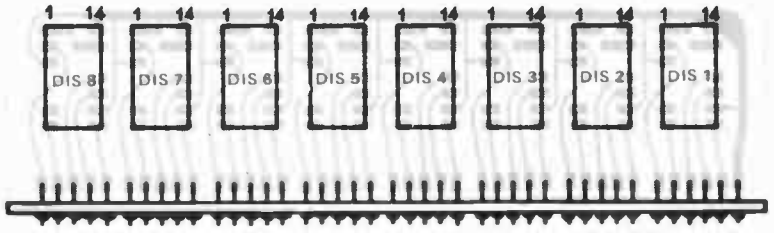

Fig. 13. Component overlay of the display board.

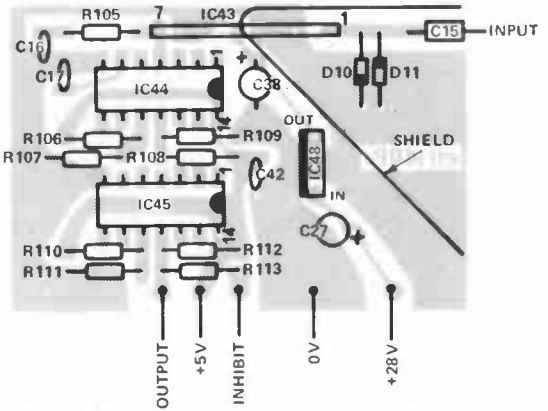

Fig. 14. Component overlay of the prescaler.

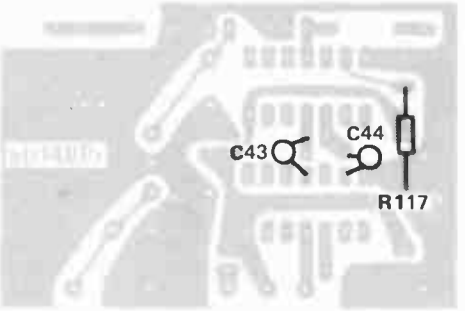

Fig. 15. View showing the position of C43, 44 and R116 on the rear of the prescaler board.

World Radio History

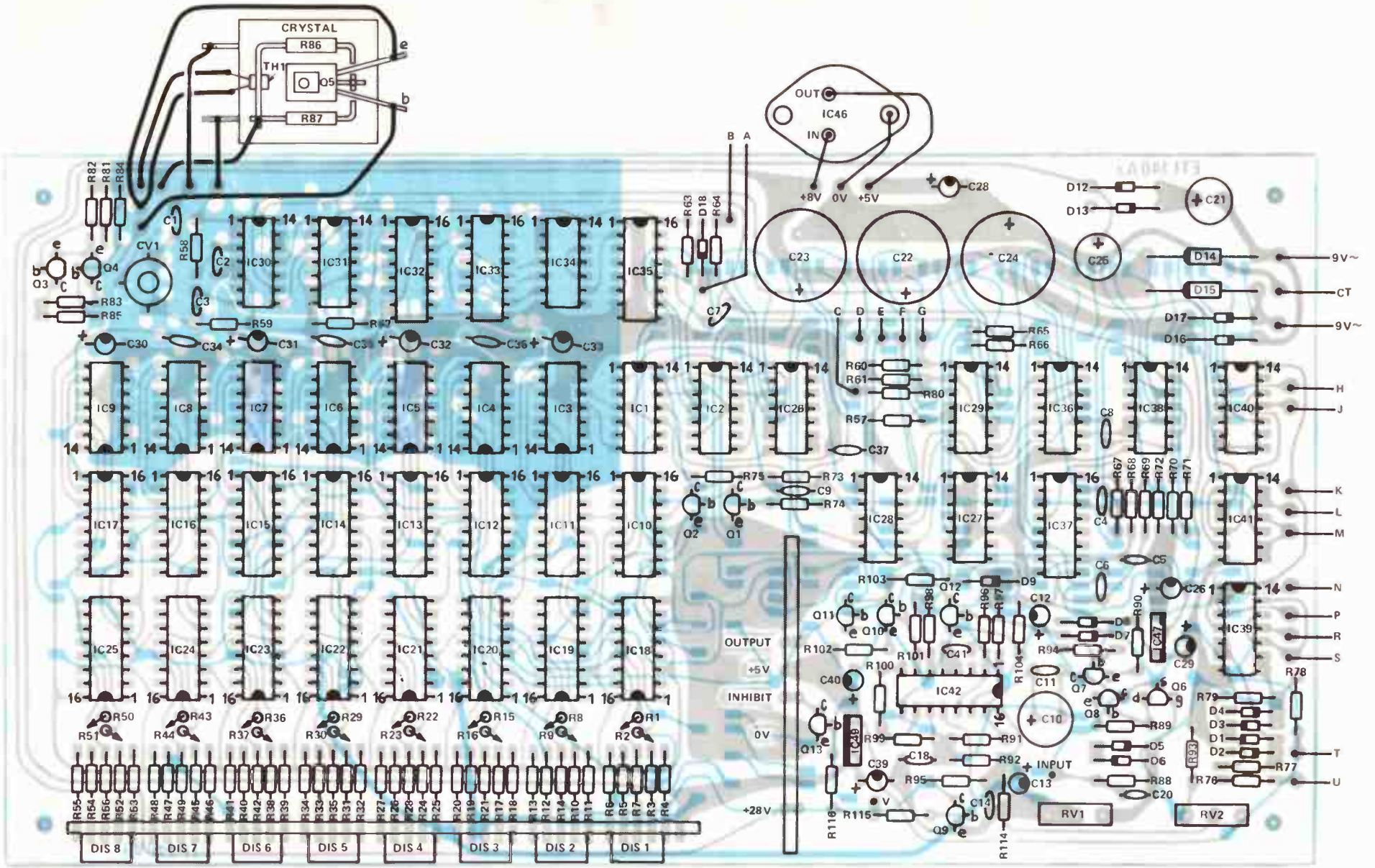

Fig. 16. The main component overlay. For the connection of wires marked A — U see Fig. 8. Wire B goes to the decimal point on DIS 5 (Pin 6) while wire C goes to the decimal point of DIS 1 (Pin 6).

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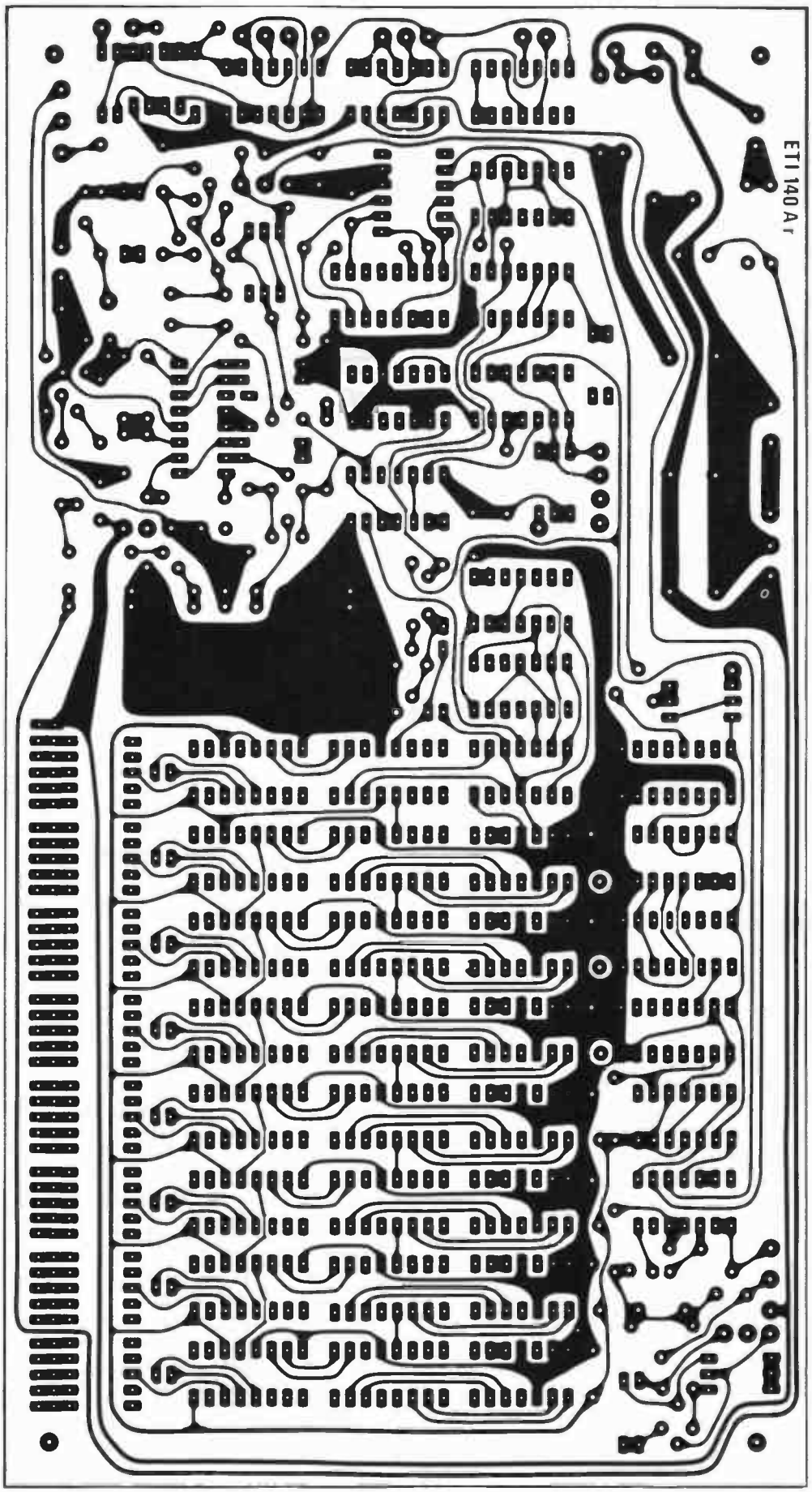
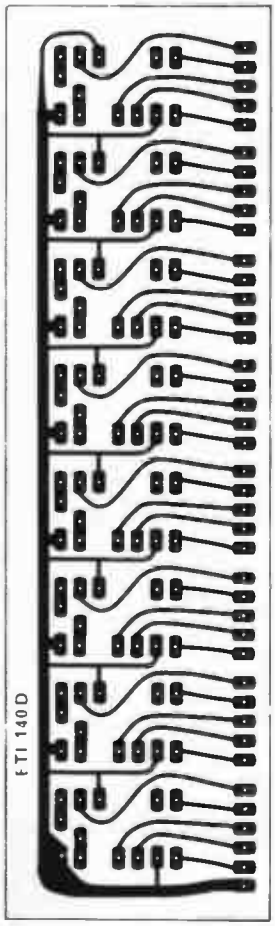
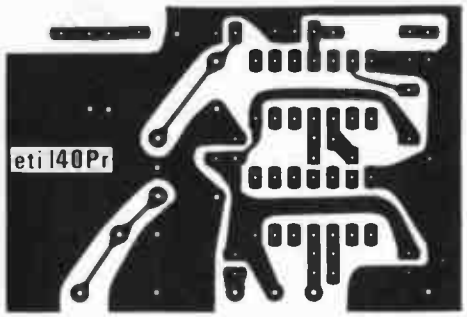
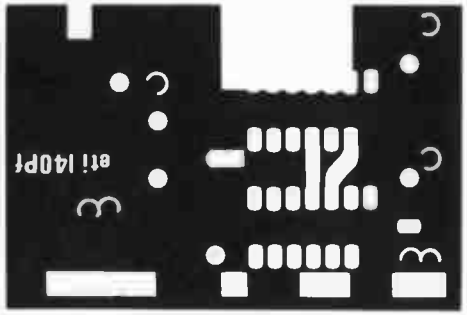
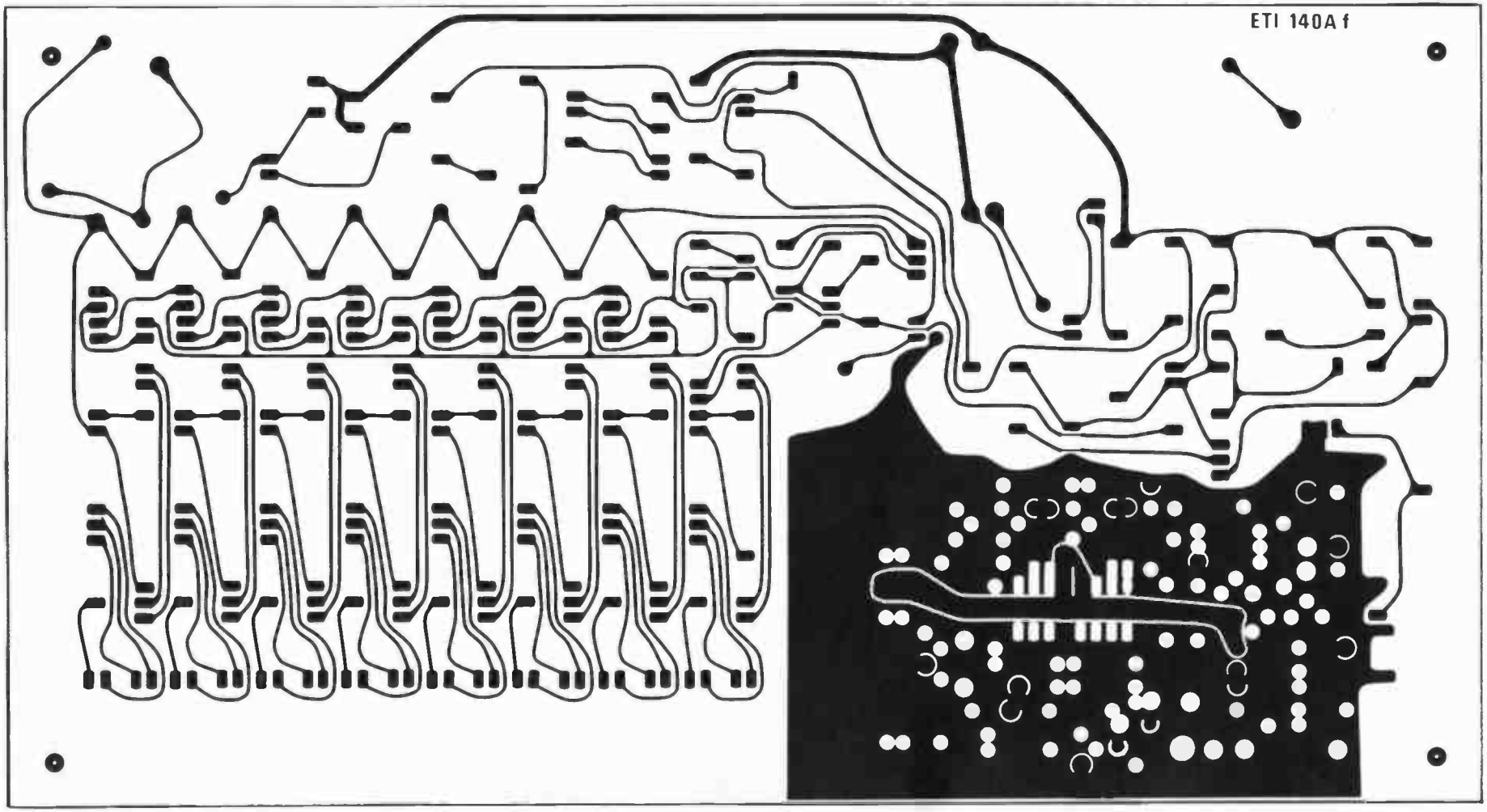




World Radio History







World Radio History

Getting the best from the ETI-140 1GHz DFM

HERE ARE a number of hints and tips to help you get the best from your instrument.

First some general advice:—

Due to the high gain and fast switching internally, the unit should be used with the lid on and with shielded cable to the unit. Failure to do this may lead to oscillations at low frequencies due to pickup in the external leads.

The method of compensating for the strobe-reset time by changing the crystal frequency slightly leads to an error of about +0.00005% when using the UHF input which uses the 1.6 second time base. Therefore, where greatest accuracy is needed, the unit should be calibrated using the input.

Crystal oscillator

The oscillator stability is the main limitation on ultimate performance, as would be expected. Experience indicates that, despite the crystal oven (which works quite well), temperature changes affecting the 74LS00 oscillator/driver affect the frequency of oscillation, limiting the accuracy to a few parts per million.

This is quite satisfactory for many purposes, but, where greater accuracy is required, particularly where the full display facilities are to be used to best advantage, then an 'add-on' high stability oscillator is recommended (see following notes).

It may be found that some crystals will not 'behave' in the circuit as published. The solution lies in tailoring some of the oscillator components to suit the crystal used.

For starters, R58 and R59 may be adjusted to give the correct drive level to the crystal. Reliable starting and improved stability result from a little 'juggling' of these resistors. Not all crystals have the same characteristics.

Too high or too low a drive level may cause unreliable starting and possible harmonic or sub-harmonic oscillation. (e.g. rather than the oscillator operating on 4 MHz as intended, it may produce 8 MHz or 2 MHz). In addition, too low a drive level increases frequency drift. The correct level is best found experimentally if you experience trouble in this department.

Note that capacitor C3 is a bypass intended to suppress harmonic operation of the oscillator. However, with some crystals it may bring about sub-harmonic oscillation!

From experience, some crystals require R58 and R59 to be 470 ohms and C3 to be left out for best operation of the oscillator/driver. Still others need these resistors to be at least 1k, C3 being retained in this case.

Additionally, it has been noted that the value of C4 may need to be increased to achieve correct operation on frequency and period modes. A value of 330 pF is suggested as a starting point.

In some units, problems have occurred in the frequency and period mode caused by the delay between the strobe and reset pulses not being long enough. This can be cured by parallelling R68 with a IN914 diode, cathode to pin 4 IC37 and if necessary increasing C5 to 1n5.

Longer gate times

The standard gating time of one second (1.6 S on prescale) is a good compromise between accuracy and reading delay, chosen to suit the majority of applications envisaged for this instrument. While the period mode should be used for accurate readings on low frequencies (crossover point for best resolution is around 3000 Hz) longer gating times of 10 seconds, or even 100 seconds, can be provided by adding extra stages to the divider chain. This is desirable at lower frequencies where resolution is the important factor.

If the extra stages are connected at the output of IC31 (pin 9), the range of the time and period functions will be increased, but, at the same time the resolution will be reduced. Low power Shottky devices — 74LS90s — are recommended. Note that CMOS 4518s require buffering to drive the 74S10, and are therefore impractical.

Sensitivity control

In our design, the sensitivity control operates opposite to the convention; i.e. maximum sensitivity is obtained when the control is wound fully anti-clockwise, If desired, this can be reversed as follows:—

On the pc board (page 56), cut the track connecting the centre pin of RV1 and connect the centre pin of the pot to the opposite pin instead.

For many applications, a linear pot will provide a more 'controlled' rate of attenuation.

Note that the DC shift control is 'off' when it is centred.

Prescaler pointers

Constructers should follow stringent RF construction practices in order to avoid problems with the prescaler — particularly around the OM335.

Earth paths are critical at UHF. All components should be soldered both above and below the board where indicated, especially the earth leads of the OM335. This IC should mount right down on the pc board. Some ceramic material may need to be *carefully* scraped away from the pins at the component's body to enable successful soldering to the pins on the top side of the pc board.

As the OM335 provides a lot of gain in a small space the stage will tend to be unstable at best, breaking into oscillation unless care is taken to install it correctly. If you experience instability problems, check the above points first. Then, adding an extension to the tinplate shield running alongside the OM335 (refer to the photographs in the original article). These measures should be completely effective.

The 'Maximum input' of 200 mVac specified for the ETI 140 refers to the input impedance of 75 ohms. Above this level the input protection diodes reduce the impedance. Specified maximum input to the OM335 itself is about 2.5 V. The diodes will protect it from most overloads, but to retain system impedance during measurements and to give the maximum overload safety margin, input level should be kept well below the specified maximum.

Fortunately, the sensitivity is so high, at least 20 mV at 50 MHz and improving with increasing frequency, that for most applications direct connection to a circuit is not necessary and a small pickup loop on the end of a coax lead is all that is required to obtain an adequate measurement.

Displays

The DL707 display specified is an industry standard and can be obtained under a variety of part numbers. Some of these, for example, are:

MAN72A	TIL312	5082-7650
745-0017	5082-7610	

World Radio History

Some constructors who used the XAN3062 display, substituted for the DL707, found them unreliable. If DL707s are unavailable, any of the above may be substituted.

Power supply

Do not be bothered (. . . my little chicken – as the fairy story goes) that the transformer specified (Ferguson PL18/20VA) gets quite hot. This is not because it is overloaded, rather it is designed to run at a relatively high temperature. It conducts a fair amount of heat through the chassis, which, naturally enough, gets quite warm. The internal temperature remains within tolerable limits. If you're worried about it, either run the unit with the lid slightly raised or put ventilation holes in the lid.

When attaching the external wiring to the pc board, a little extra length will allow the board to be pivoted forward to allow access to the underside for service. Not shown in Figure 8 (April 78 issue, p.79) is an extra connection from point 'E' to the main board. The type 8168 pushbutton switch specified for PB1 has not been available for some time, due to production problems we are told. Type 8121 may be substituted. The connections are different but, referring to figures 8 and 16 in the April 1978 issue and the markings on the switch, correct wiring is readily ascertained.

When troubleshooting

The apparent complexity of the instrument may make the task of servicing or debugging seem daunting. However, if the unit is treated in its separate sections it becomes fairly straightforward.

Firstly, it is essential that the unit not be switched on without the earth lead from the chassis to the pc board earth pattern or the 9582 (IC42) will be damaged. If a prescaler is fitted the earth should go from a lug under the prescaler input socket to the earth pattern of the prescaler board – use a short, heavy lead.

A divider probe must be used when checking operation of the ECL devices with a CRO, otherwise oscillation may result. A 'x10' probe is recommended, but should not be used on the ECL/TTL translator.

Note that it is normal of ICs 42 to 45 and 47 to 49 to run hot.

Exercise care when removing ICs from the board to avoid damage. The safest way in the absence of special equipment is to use a solder sucker or 'solder wick' to remove solder.

Add-on crystal oscillator

Improved short-term and long-term stability can be obtained by constructing a separate oscillator and buffer and incorporating the whole assembly with the oven components suggested in the article on ETI 140.

A suitable oscillator circuit is given here. Capacitors C1 and C2 should be either silver mica or polystyrene types. Exact value is not critical and one value either side of those specified may be used. The two 10n (0.01 uF) bypass capacitors should be ceramic types. The output capacitor from the collector is best chosen by experiment, depending on the buffer used. More on this later.

The 2k2 resistor marked 'Rf' determines the level of feedback, and to a certain extent, affects the ultimate stability as it isolates the crystal from the active device and the load. It should be chosen such that reliable starting is obtained, with the highest tolerable value. One standard value lower than that determined by experiment for reliable oscillator starting is the best bet. Note that it may take some seconds for the oscillator output to appear and rise to maximum level following switch on with this circuit.

The 5-60 pF trimmer is used to set the frequency exactly. A miniature Philips film trimmer or (if you have the space) a mica compression trimmer should be used.

A CMOS Schmitt trigger, to provide logic level output, is recommended as a buffer. The coupling capacitor from the oscillator collector should be chosen to be as small a value as possible, consistent with reliable operation of the Schmitt trigger. A value of 100 pF is a good place to start.

All these measures isolate the crystal from the cruel vicissitudes of the 'outside world'.

The crystal, oscillator components, buffer and oven components should all be mounted in a thermally-insulated container – polystyrene foam blocks are ideal, as mentioned previously. The crystal should be mechanically (and thus thermally) connected to the oven components as detailed in the original article. Having some thermal linkage to the other components is also a good idea, however, this is left to the individual constructor's ingenuity.

Output from the buffer can be taken direct to the divider chain.

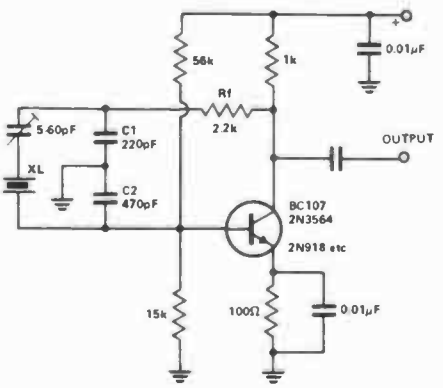
Only common and +5 V supply are the other connections necessary.

Crystal specifications

No specifications were given in the original article for the crystal. Not all crystals are the same. The following set of specifications is recommended.

Frequency:
4.0000 MHz
Manufacturing tolerance:
+/- 20 ppm
Temperature tolerance:
+/- 20 ppm,
-10 to +55°C
(or 0 to +60°C)
Load capacitance:
32 pF (or 30 pF)

The crystal can be obtained in either the HC6/U (13 mm pin spacing) or the smaller HC18/U package – the latter is preferred for space reasons. Either pins or flying leads may be ordered for the crystal connections. ●



Suitable oscillator circuit for the add-on crystal oscillator. The output should be taken to a CMOS Schmitt trigger buffer to provide logic level output.

The assistance and cooperation of John Rileagh, of JR Components, in preparing these notes on the ETI 140 DFM is greatly appreciated.

World Radio History

Project 134

TRUE RMS VOLTMETER

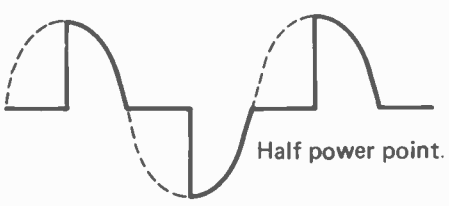
The use of a special IC results in performance greatly improved over conventional designs.

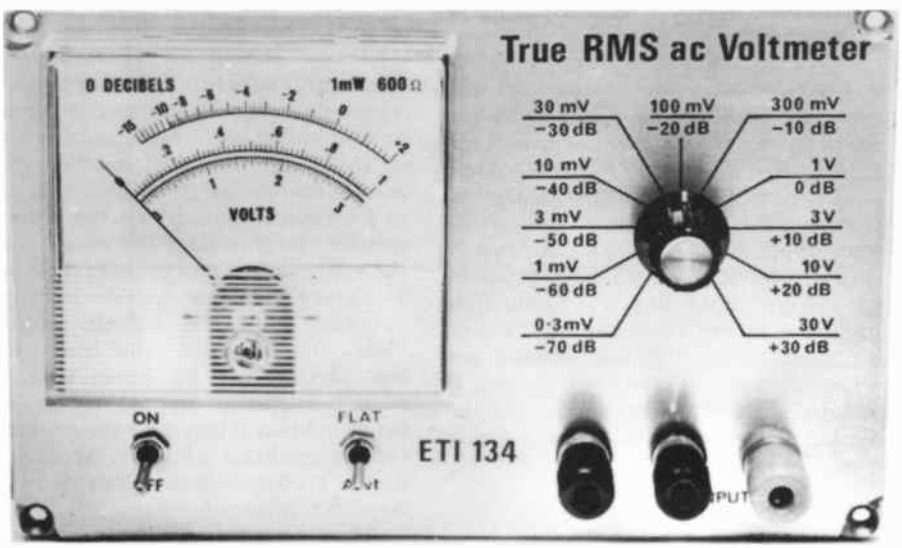
MOST METERS which can measure ac signals do so by rectifying the signal and then measuring the average voltage. With a sinewave the average voltage is 0.637 of the peak voltage while the rms value is 0.707 of the peak. Therefore a correction factor of 1.11 is built into the meter to give the rms value of the signal.

Provided you stick with sinewave signals these meters are adequate. With any other waveform, however, they are not accurate. With a square wave the error is 11% and with pulse wave forms the error increases.

Before continuing we should explain what rms means and its significance. Without getting mathematical, the rms value of any wave form is the same as a dc value which would produce the same heating effect in a resistor. For example:

Power in a load can be varied by using phase control (i.e., light dimmer) where the time the load is connected to the mains is variable. The rms value is difficult to calculate except at the point where it is half on–half off. The power then is obviously half power.





If the input voltage is 240 V and the load is 240 ohms the power (maximum) is given by

$$P = \frac{E^2}{R} \text{ or } \frac{240 \times 240}{240} = 240\,W$$

Half power therefore is 120 W. The voltage corresponding to this is given by

$$E = \sqrt{P \times R} \text{ or } 170\ V\ (rms)$$

On a "normal" meter this will read 120 V or an error of 30%.

This design uses an rms detector IC, which is basically a small, special-purpose analogue computer to mathematically calculate the true rms value for any waveform.

Design Features

The design of the voltmeter is basically simple, starting with an attenuator in the front end, then an amplifier with a high input impedance and switchable gain which, with the attenuator, gives the range selection. A filter is then added to give the "A" weighting and the rms detector IC (LH0091) does the rest.

The output of the input amplifier is 60 mV, independent of range selected, for an input corresponding to the full scale reading. This gives a maximum gain of 46 dB on the 0.3 mV range. There is a loss of about 2.3 dB in the filter (at 1 kHz) and the spare amplifier in IC2 is used to provide a gain of 20 dB giving 500 mV (for full scale reading) before the rms detection is done. The

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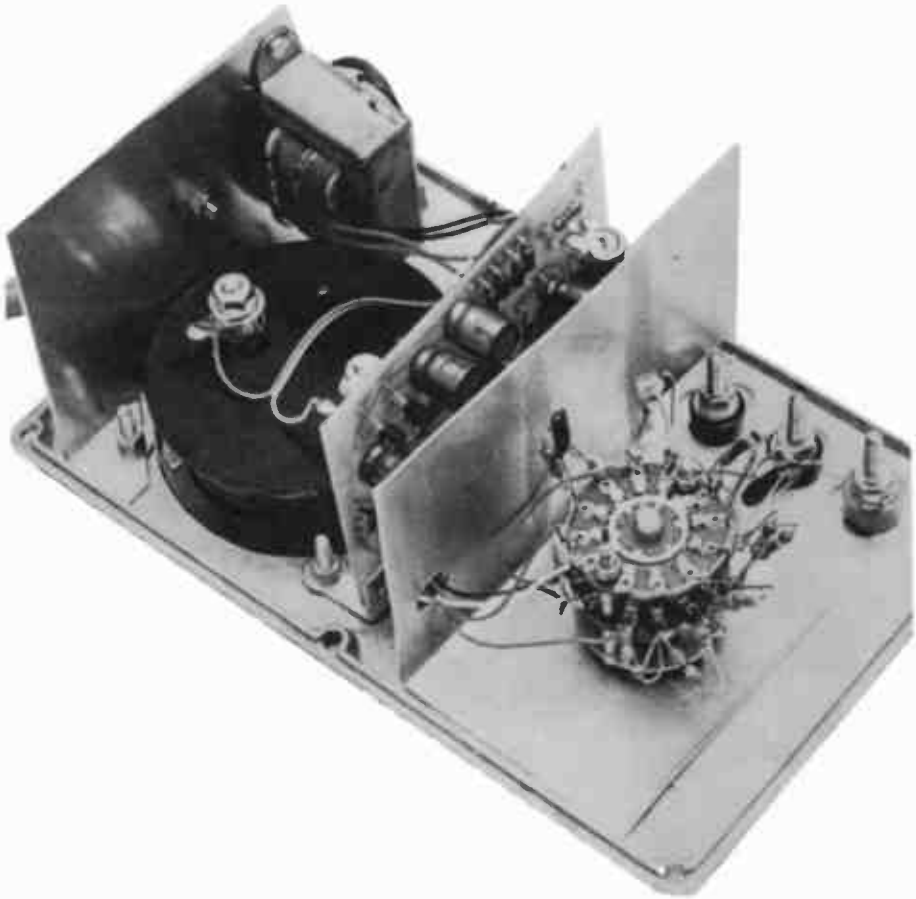


SPECIFICATION – ETI 134

Meter Type	rms reading ac only
Ranges	0.3, 1, 3, 10, 30, 100, 300 mV 1, 3, 10, 30 V
Accuracy	±3% nominal (crest factors up to 3) – 8% at crest factor of 10
Input Impedance	1 megohm in parallel with 25 pF
Weighting Networks	Flat or 'A' weight
Frequency Response	10 Hz – 20 kHz

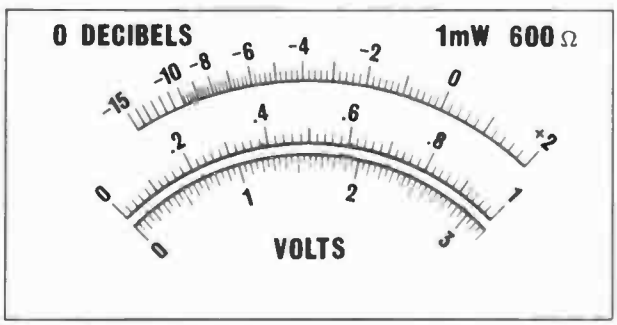


Fig. 1. Meter scale shown full size.

rms detector section has unity gain with 500 mV rms in giving 500 mV dc out.

However things are never that simple. With a total of 60-odd dB gain, along with the requirement for a 1 M input impedance, we have an excellent formula for an oscillator. With the third try (yes, we have failures too) with adequate shielding and layout, stability was obtained and this final design is presented here.

The spare IC in the LH0091 is normally used to buffer, filter or amplify the output of the rms converter but we used it before so as to buffer the filter network and save an additional op amp (the input of the rms converter is only 5 k ohms). The output voltage from the converter is only 500 mV but this is adequate to drive a meter. We could have provided more gain in the buffer stage so giving a higher output but this would lead to greater errors with high crest factor waveforms.

We have limited this instrument to ac signals as this eliminates the need for balance controls to correct for drift when measuring low level signals. This normally is of no consequence as most signals, i.e., output of a tape recorder, sound level meter, etc., have no dc component. If dc capability is needed, capacitors C1, 8, 9, 14, 15 and 16 have to be shorted out, a zero adjustment potentiometer added to IC1 along with the potentiometers needed to offset adjust IC2.

Construction

If the printed circuit board is used along with the layout and shields as described there should be no problems with construction. The wires associated with the rotary switch should be no longer than necessary to minimise any pickup. The box should be earthed to the mains earth and the front panel earth terminal (left hand one) should also be connected to earth.

Use

When measuring low level signals there may be 50 Hz pickup unless the common side of the input signal is connected to ground. This may be done either in the unit under test or on the meter (hence the earth terminal). Also with the meter terminals open circuited the meter will give some reading. However, as the output impedance of low level signals (0.3 mV and less) is normally relatively low this is normally no problem.

World Radio History

TRUE RMS VOLTMETER

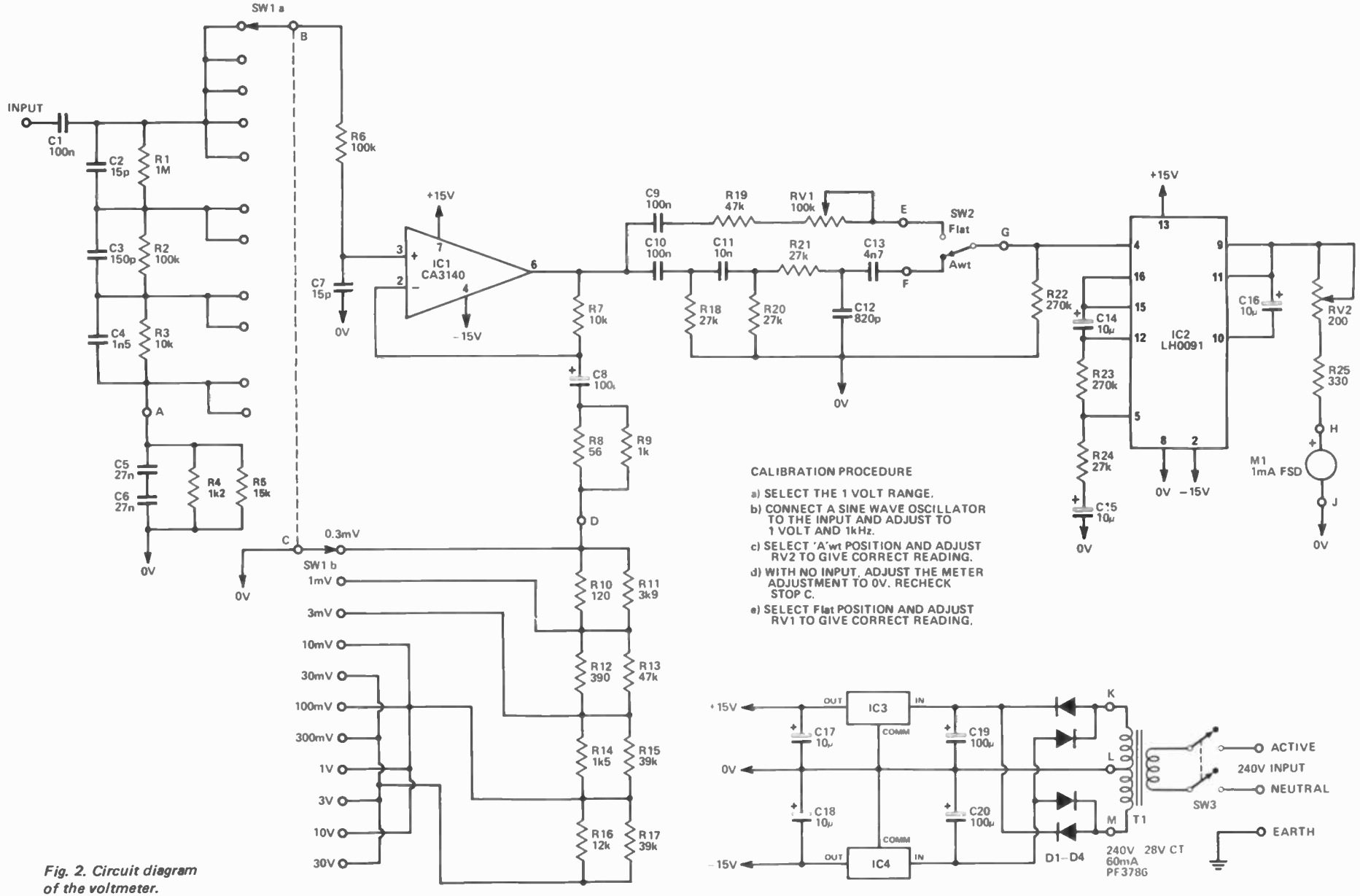


Fig. 2. Circuit diagram of the voltmeter.

World Radio History

HOW IT WORKS – ETI 134

The input signal is attenuated by the network R1–R5 and C2–C6; the appropriate attenuation is selected by SW1a. This gives 0 dB, 20 dB, 40 dB and 60 dB. The output of SW1a is buffered by IC1 which is a FET input op-amp. This amplifier has a gain which is switchable giving 5.56 dB, 15.56 dB, 25.56 dB, 35.56 dB and 45.56 dB. By selecting a combination of these two variables the eleven ranges from 0.3 mV to 30 V are obtained. The output of IC1 for full scale reading is 60 mV.

The output of IC1 goes to the 'A' wt filter network and also directly (via R19 and RV1) to SW2. This selects either 'A' weighting or flat response. As the filter has 2.3 dB loss at 1 kHz the "flat" position is also attenuated (hence R19, RV1) to maintain calibration.

The rms detector IC provides a gain of 20 dB before the detector; the output of the detector is about 500 mV for full scale reading.

The power supply is simply a full wave rectified supply giving both plus and minus voltages of about 20 V, which are then regulated to ±15 V by IC3 and IC4.

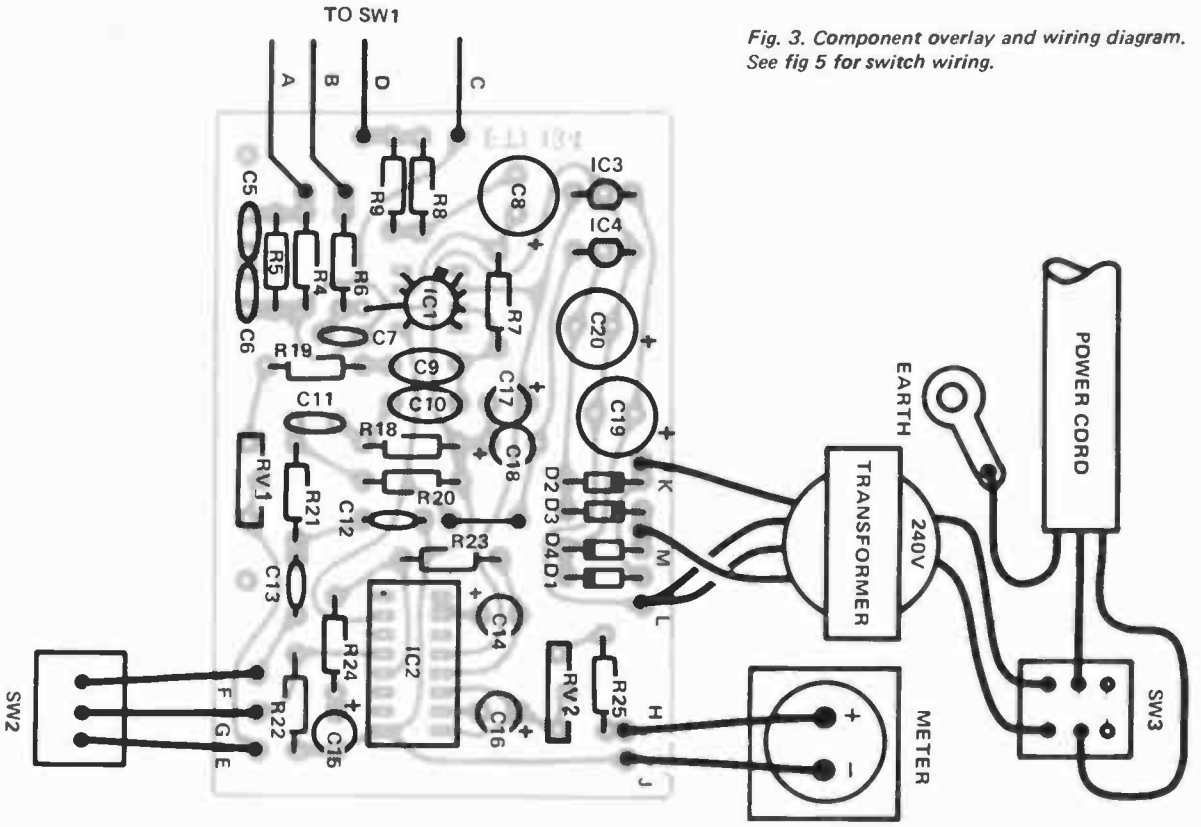


Fig. 3. Component overlay and wiring diagram. See fig 5 for switch wiring.

PARTS LIST - ETI 134

Resistors

All ½ W 5%, except where marked.

R1	1M	1%
R2	100k	1%
R3	10k	1%
R4	1k2	1%
R5	15k	
R6	100k	
R7	10k	1%
R8	56	1%
R9	1k	
R10	120	1%
R11	3k9	
R12	390	1%
R13	47k	
R14	1k5	1%
R15	39k	
R16	12k	1%
R17	39k	2%
R18	27k	
R19	47k	
R20,21	27k	
R22,23	270k	
R24	27k	
R25	330	

Potentiometers

RV1	100k	trim
RV2	200 ohm	trim

Capacitors

C1	100n	polyester
C2*	15p	ceramic
C3*	150p	"
C4*	1n5	polyester
C5, 6*	27n	"
C7	15p	ceramic
C8	100µ	25V electro
C9, 10	100n	polyester
C11	10n	"
C12	820p	ceramic
C13	4n7	polyester
C14-C18	10µ	25V electro
C19, 20	100µ	25V electro

* These capacitors should be as accurate as possible as they affect accuracy above 10kHz.

Semiconductors

IC1	CA3140	op amp
IC2	LH0091	RMS converter
IC3	78L15	regulator
IC4	79L15	regulator
D1-D4	1N4001 or similar	

Miscellaneous

PC board	ETI 134
SW1	2 pole 11 position OAK switch
SW2	SPDT minature toggle switch
SW3	DPDT minature toggle switch
T1	Transformer PF3786 (28V ct)
M1	Meter 1mA scaled as shown

3 terminals (red, black green)
Box Eddystone 6357P
Metal brackets and shields (see Fig 7)
3 core flex and plug
Scotchcal or aluminium front panel
16 pin socket for IC2
Knob

World Radio History

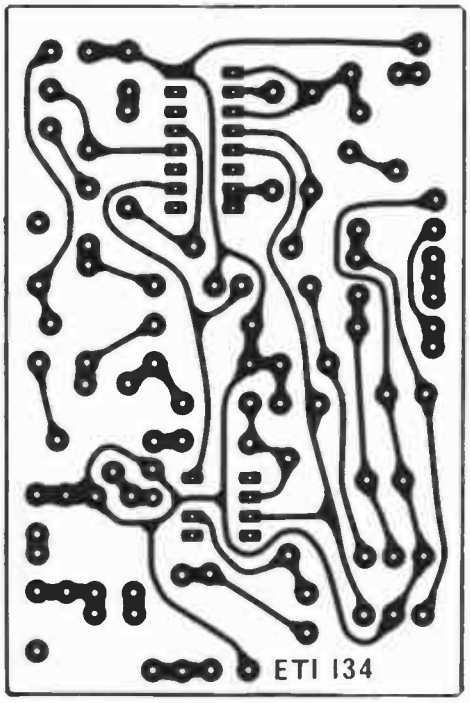


Fig. 4. Printed circuit layout.
Full size 90 x 60 mm.

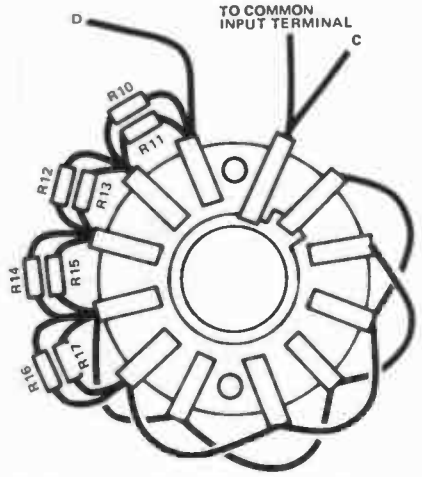
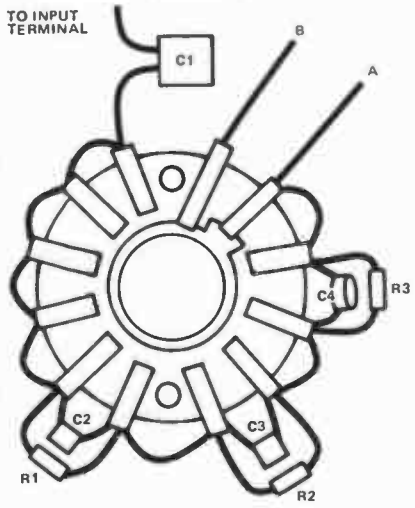


Fig. 5. Connection of the range switch drawn in the 30 V position.



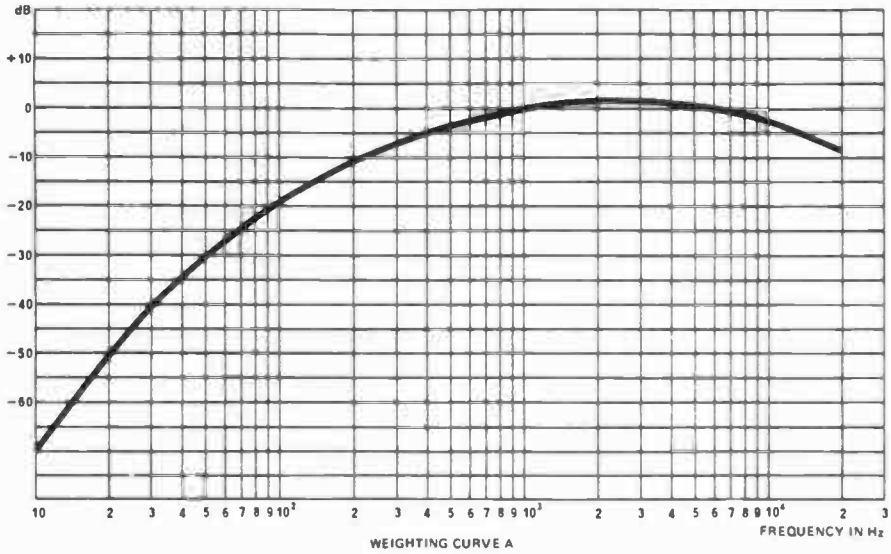


Fig. 6. The response in the "A" weight position.

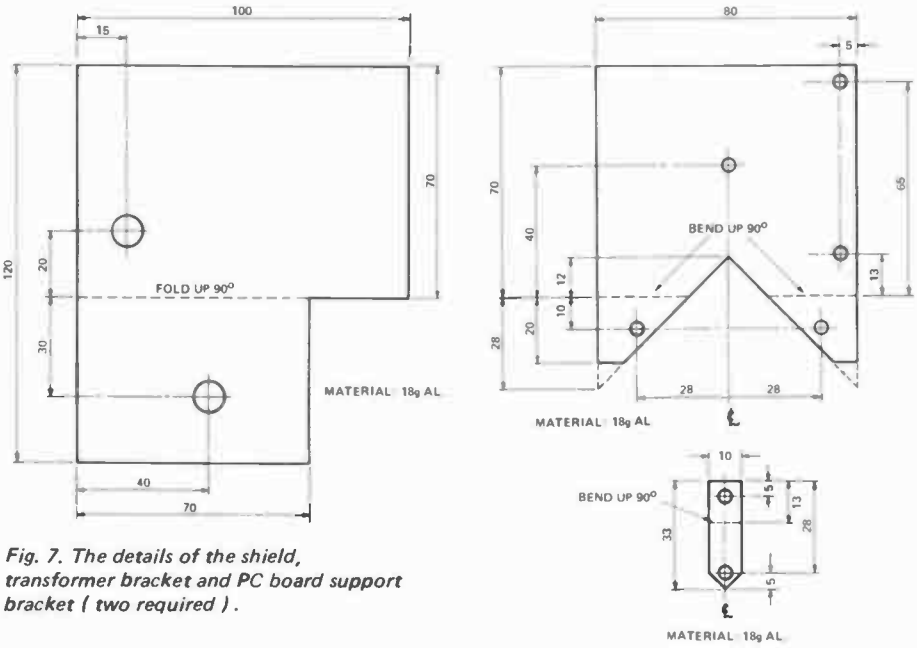
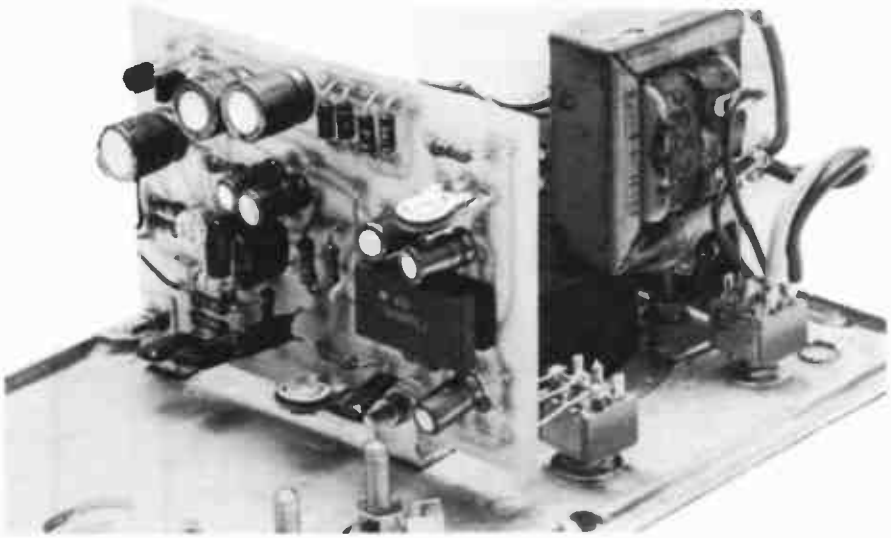


Fig. 7. The details of the shield, transformer bracket and PC board support bracket (two required).



World Radio History

Project 144

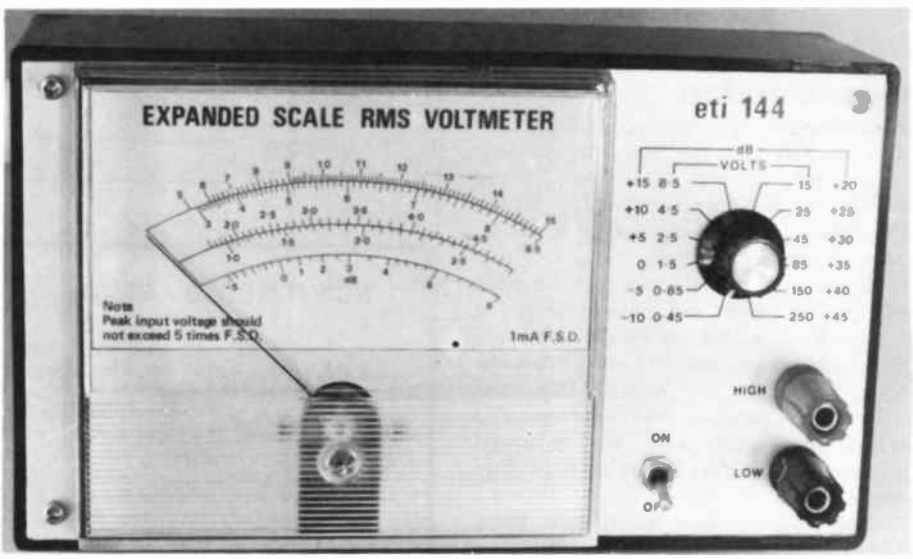
Expanded scale RMS voltmeter

Barry Wilkinson, of Nebula Electronics, needed to develop an RMS voltmeter to measure dc pulses in a particular application for a customer of his. It was only a few steps from there to this project.

THE RMS VOLTMETER described in the previous article is an ac only instrument which uses an LH0091 RMS converter IC.

The instrument described in this article, while perhaps not as versatile in some ways as the ETI 134 which has a 0.3 mV to 30 V range and an A-weighting filter, is simpler to construct, will measure dc signals (square waves and pulses etc referenced to zero volts) and is less expensive.

This instrument will measure 150 mV to 270 V in 12 ranges and features a large (90 mm scale) meter, 2% accuracy and an expanded scale for ease of reading.



What is RMS?

At this stage, it would be a good idea to recap just what RMS means and its significance. Simply, the RMS value of any waveform is equal to that dc value which would produce the same heating effect in a resistor.

As an example, let's take the case of a light dimmer. The power in the light (the load) is varied using phase control in an SCR circuit. This varies the amount of time the load is connected to the mains over part of each mains cycle (see Fig. 1). The RMS value of the waveform across the load in this case is difficult to calculate, except at the point where it is half-on and half-off. The power is then obviously half the maximum value.

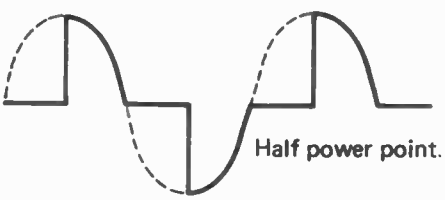


Fig. 1. The output waveform of a light dimmer running at half power.

If the input voltage is 240 V and the load is 240 ohms, the power at maximum can be calculated from:—

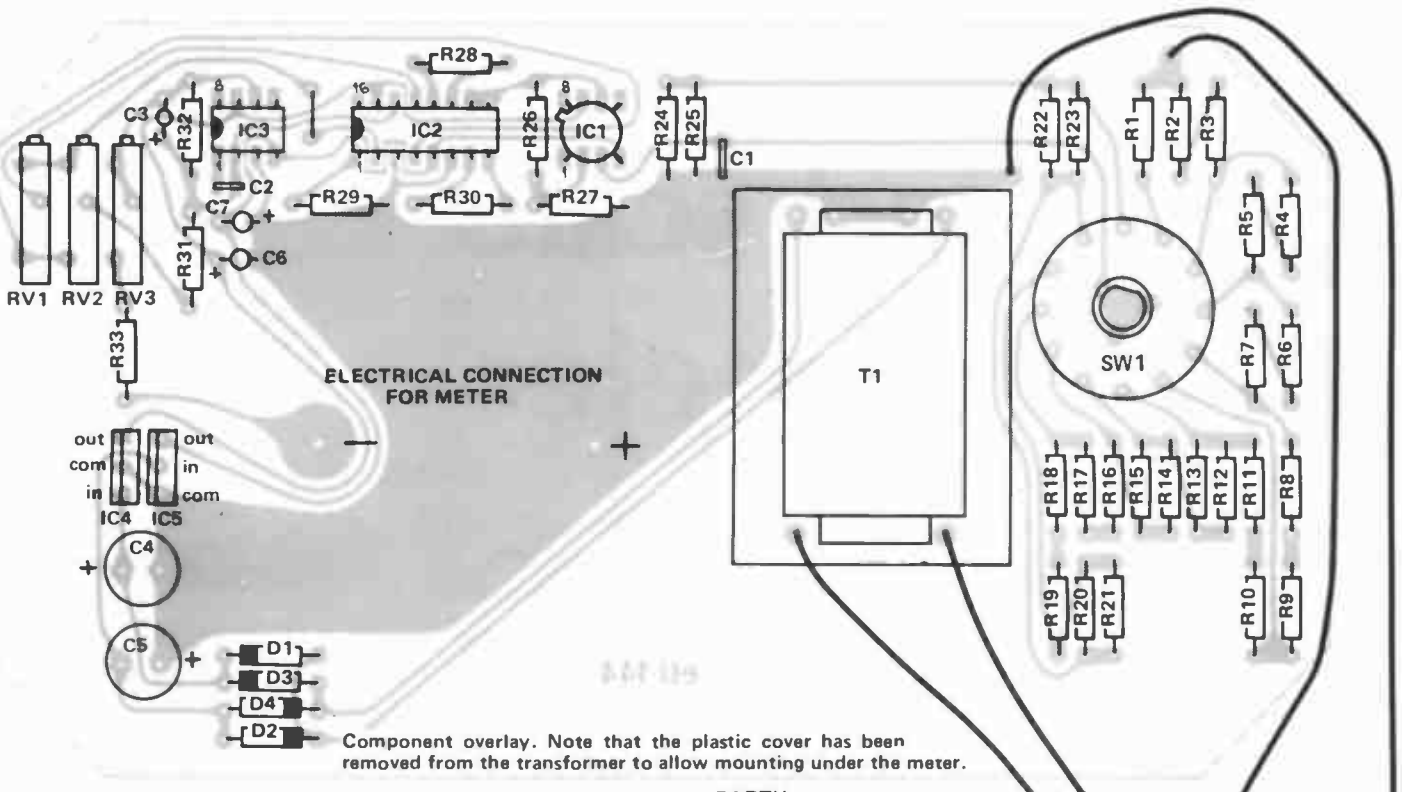
$$P = \frac{E^2}{R} \text{ or } \frac{240 \times 240}{240} = 240 \text{ W}$$

Half power is therefore 120 W. The voltage corresponding to this is given by:—

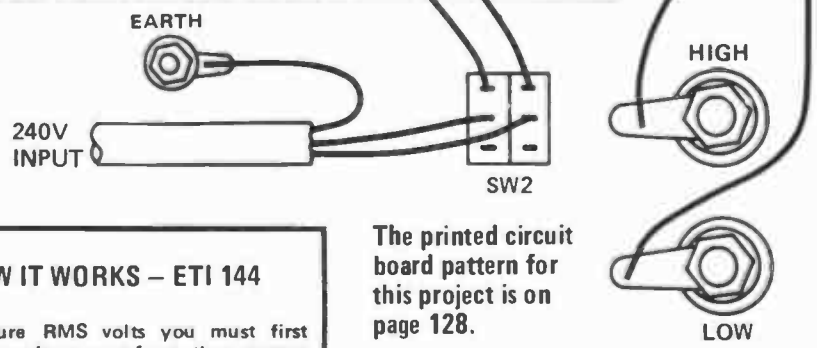
$$E = \sqrt{P \times R} \text{ or } 170 \text{ V (rms)}$$

On a 'normal' meter this will read 120V, — an error of 30%. ▶

World Radio History



Component overlay. Note that the plastic cover has been removed from the transformer to allow mounting under the meter.



Construction

Assemble the pc board according to the overlay diagram, starting with the low height components. Do not fit the switch or the transformer yet. Watch the polarity and orientation of the components before soldering.

Before the transformer can be used the plastic cover and base have to be removed to reduce its height. This can be easily done using a small bladed screwdriver. Do not remove the internal plastic cover over the windings. The transformer can now be mounted and soldered in place keeping it as close as possible to the board.

The rotary switch specified (C & K 1054) is a pc-mounting type but may not be as readily available as the CK1034 type which has wiring connections. This can be used however if the very ends of the terminals are cut off carefully When fitting it to the pcb ensure that the No. 1 pin is toward the top of the board. Do not solder yet.

Fit the Scotchcal panel to the aluminium front panel and drill all the holes. Fit the meter to the panel. Assemble the power switch and terminal posts to the panel. Attach wires, about 100 mm long, to the terminal posts and also wire up the power switch. Earth the front panel using one of the meter retaining screws and leave about 50 mm of wire on the two outputs from the switch.

HOW IT WORKS – ETI 144

To measure RMS volts you must first square the voltage waveform, then average it and finally take the square root of that average. In this unit we electronically square and average the input but we use the meter scale to take the square root.

The input voltage is divided by the input network such that the input IC1 is 0.47 volts (dc or RMS) for full scale deflection. IC1 provides buffering and a gain of two.

Squaring of the output of IC1 is done by IC2 (1494), a four quadrant multiplier, which gives a current output proportional to the product of the voltages at its two inputs (pin 9 and 10). As we are feeding the same signal into both inputs the result is the square function.

The output of this IC is a current which is converted to a voltage by IC3 which also provides the averaging network (C3, R32). its output drives the meter whose scale is a square root function.

Adjustments are provided for the input offset of IC2 (RV1) output offset (RV2) and overall calibration (RV3).

As the power requirement of all the ICs is +/– 15 V we use a mains supply and three-terminal regulators. Current drain is about 15 mA on both supplies.

The printed circuit board pattern for this project is on page 128.

Now fit the pc board to the meter leaving the spring washers on the meter side of the board giving extra space to the front panel. As the switch now lines up with the front panel it can be soldered in place.

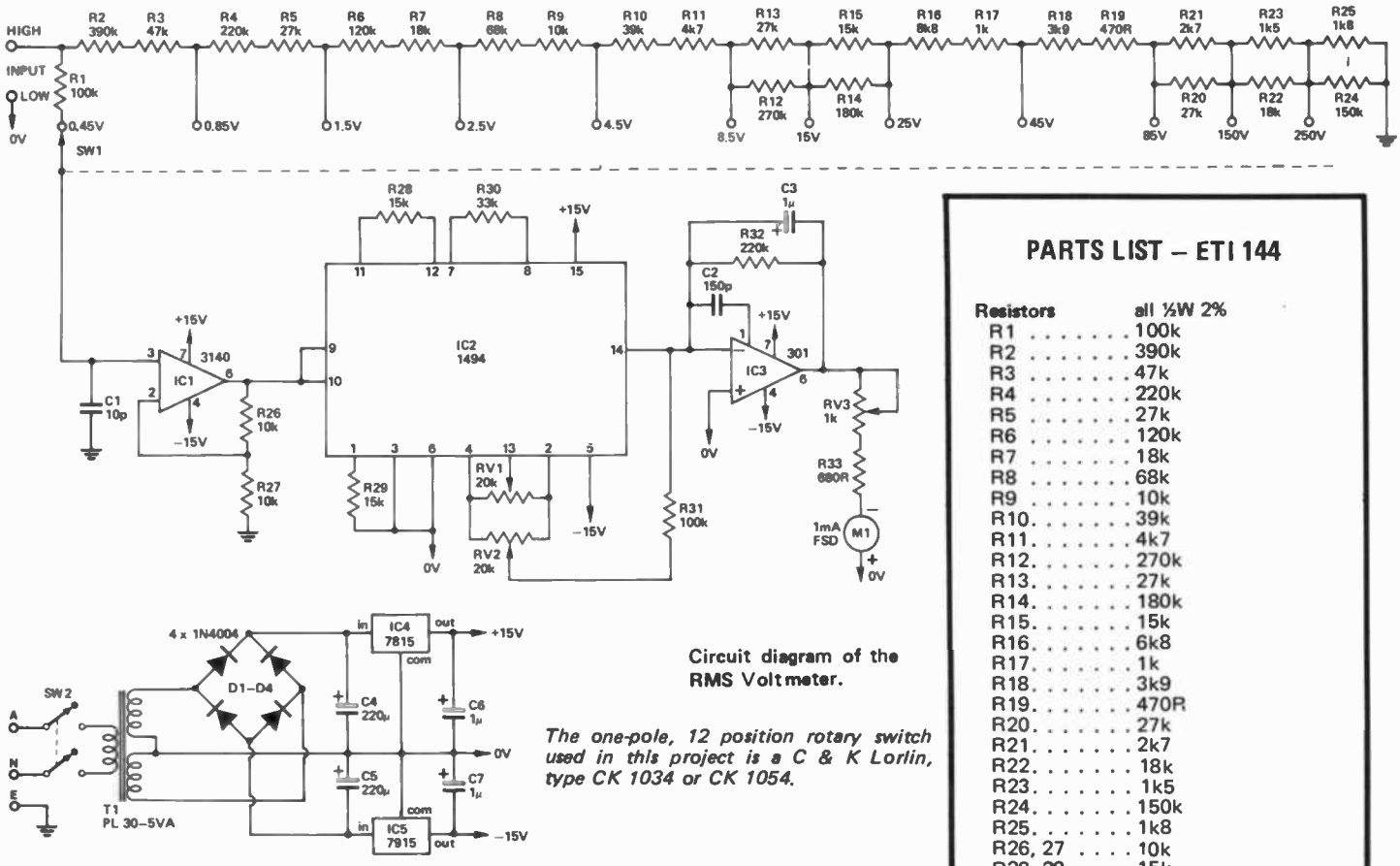
Connect the wires from the terminals to their position on the pc board. The 240 V wires from the switch come around the edge of the board and solder directly onto the terminals of the transformer. These connections should be covered with epoxy to prevent personal contact.

The meter scale can be fitted to the meter as follows:

Remove the clear cover from the meter (it clips on) then, carefully remove the existing scale. The scale should be sprayed white and allowed to dry.

Cut the Scotchcal to the borders marked, peel back the plastic a little and cut off about 5-10 mm of paper backing on one edge.

World Radio History



Circuit diagram of the RMS Voltmeter.

The one-pole, 12 position rotary switch used in this project is a C & K Lorlin, type CK 1034 or CK 1054.

ETI 144 EXPANDED SCALE RMS VOLTMETER

SPECIFICATIONS

Input range	150 mV to 270 V in 12 ranges, 5 dB apart
Accuracy	+/- 2% FSD
Crest factor	maximum, 10
Frequency response	dc to 50 kHz (sine wave)
Input impedance	1 M
Meter type	moving coil, RMS volts, expanded scale calibration

PARTS LIST – ETI 144

Resistors all ½W 2%
R1 . . . . . 100k
R2 . . . . . 390k
R3 . . . . . 47k
R4 . . . . . 220k
R5 . . . . . 27k
R6 . . . . . 120k
R7 . . . . . 18k
R8 . . . . . 68k
R9 . . . . . 10k
R10. . . . . 39k
R11. . . . . 4k7
R12. . . . . 270k
R13. . . . . 27k
R14. . . . . 180k
R15. . . . . 15k
R16. . . . . 6k8
R17. . . . . 1k
R18. . . . . 3k9
R19. . . . . 470R
R20. . . . . 27k
R21. . . . . 2k7
R22. . . . . 18k
R23. . . . . 1k5
R24. . . . . 150k
R25. . . . . 1k8
R26, 27 . . . . 10k
R28, 29 . . . . 15k
R30. . . . . 33k
R31. . . . . 100k
R32. . . . . 220k
R33. . . . . 680R

Potentiometers
RV1, 2 . . . . 20k 10 turn trim
R3 . . . . . 1k 10 turn trim

Capacitors
C1. . . . . .10p ceramic
C2. . . . . .150p ceramic
C3. . . . . .1µ 35V tantalum
C4, 5 . . . . . .220µ 35V electrolytic
C6, 7 . . . . . .1µ 35V tantalum

Semiconductors
IC1 . . . . . CA3140
IC2 . . . . . MC1494
IC3 . . . . . LM301A
IC4 7815
IC5 7915

D1–D4. . . . . IN4004

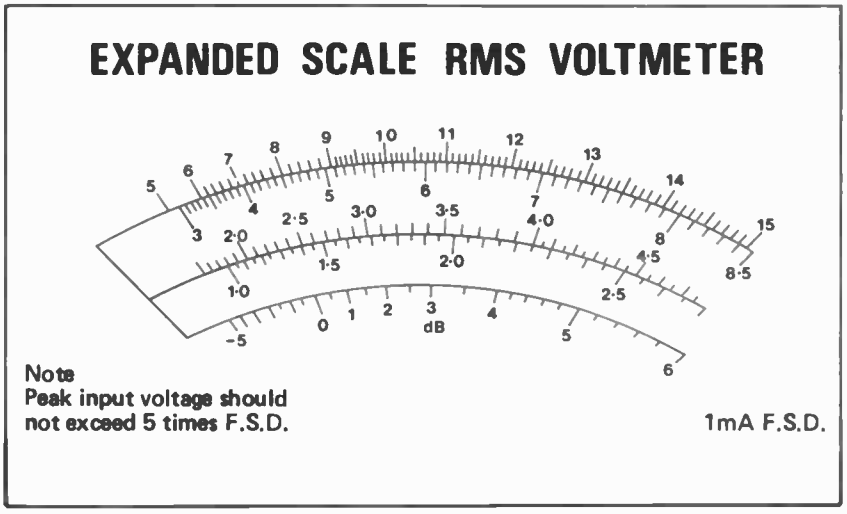
Miscellaneous
PC board ETI 144
Transformer PL30/5VA (Ferguson)
Meter TD118, 1mA FSD (University)
Meter scale to suit
Zippy box 196 x 113 x 60 mm
Scotchcal panel
2 pole power switch
1 pole 12 position rotary (see text)
Knob to suit
3 core flex, plug and clamp
2 terminal posts

The Scotchcal panel can now be placed on the meter scale and lined up while holding the sticky edge off the panel. Now press down the sticky edge to locate the panel then fold it back on itself to allow the rest of the backing sheet to be removed. Press the panel down from the edge already fixed removing any air bubbles from under it.

The scale can now be refitted to the meter and the cover placed back. ▶

World Radio History

Project 144



Both of these drawings are reproduced full size so that, if you wish, you can cut them out and use them directly.

Alignment and calibration

Equipment needed:

variable dc power supply
accurate dc voltmeter
two-pole change over switch

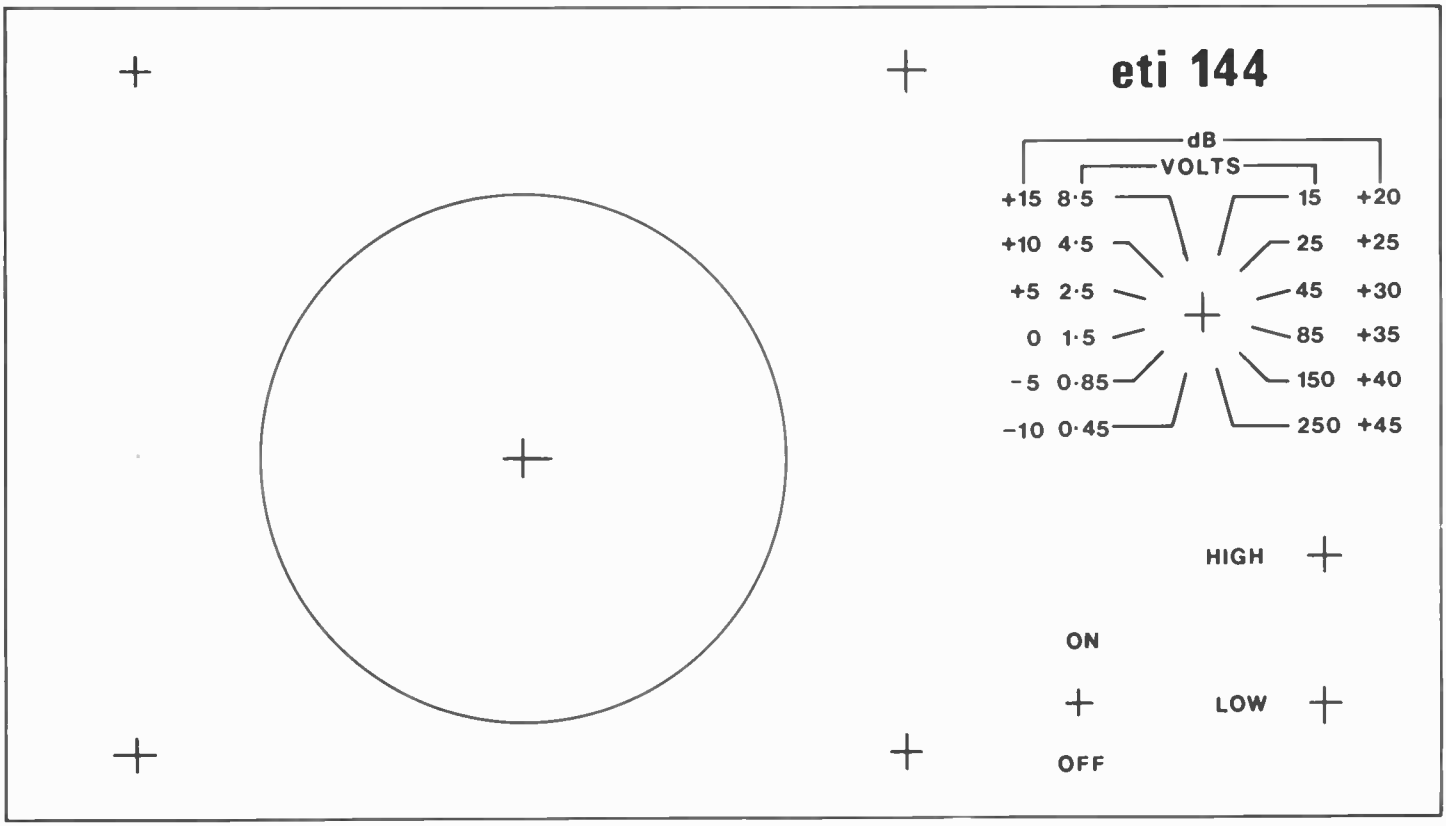
Connect the power supply to the input terminals, via the switch, connected to give polarity reversal. Switch on the unit and with no input voltage adjust RV2 to give a reading about a quarter of the way up the scale.

Allow the unit about five minutes to warm up and stabilize. You could check to see if the internal supplies are giving the correct voltages while you wait.

Now, switch to the 15 volt range and apply about five or six volts to the input. Reverse the polarity of the input and note the change in the reading. Adjust RV1 until there is no difference, irrespective of polarity.

It will probably be necessary to adjust RV2 again to keep the reading on the scale. Note that it is not the actual reading that is important just that both polarities are the same. Increase the voltage to around 14 volts to ensure the adjustment is correct.

Now, with no input voltage adjust RV2 to give a zero reading. Apply 14 volts and adjust RV3 to read 14 volts. Adjustment is now complete.

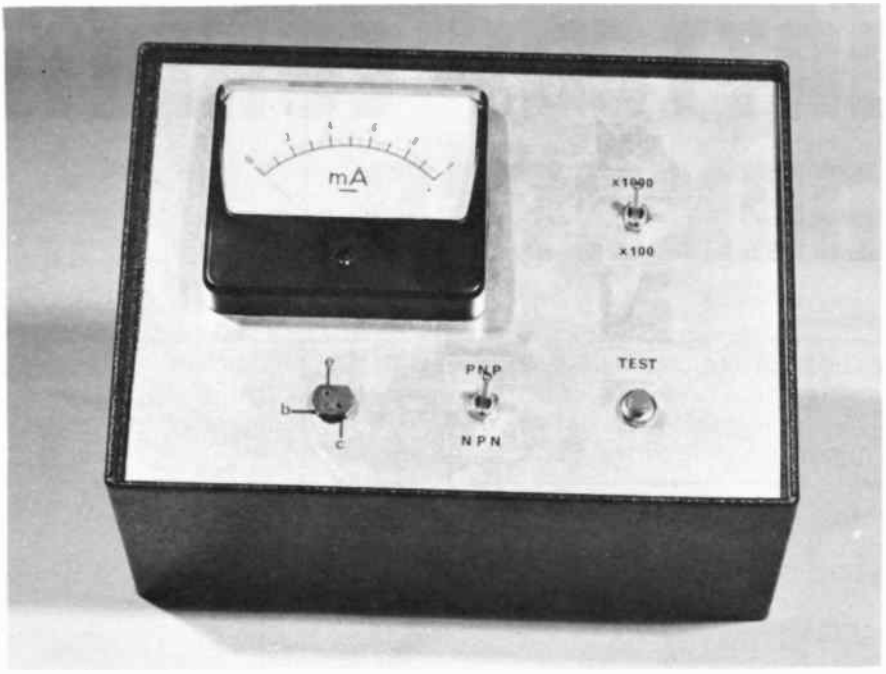


World Radio History

TRANSISTOR TESTER

PROJECT 222

Measure and test your transistors with this easily built device.



The transistor tester mounted in a metal case.

EXPERIMENTERS will frequently use the same transistors in a whole sequence of experimental circuits, for recovering and re-using such components saves considerable outlay.

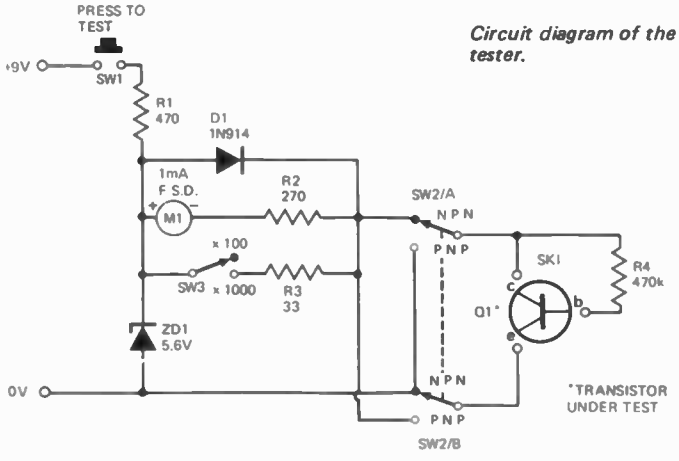
But semiconductors are easily damaged — by incorrect operating conditions — or by excessive application of heat when soldering.

Only too often a malfunctioning experimental circuit will be checked and rechecked before one realises that a transistor is dead.

A transistor tester will save hours of such frustrating and unproductive effort.

Transistors can often be bought cheaply in bulk — usually in unmarked and untested lots — or recovered from old computer boards. Here again a transistor tester will prove invaluable in eliminating the faulty bits.

The simple transistor tester described in this project not only sorts out the good from the bad but indicates also the approximate gain (β) of the transistor. This is a most useful feature for those circuits where transistors need to be matched. Two ranges of gain (beta) are provided, 0-100, and 0-1000. The tester may also be used to check transistor polarity.



Circuit diagram of the ETI transistor tester.

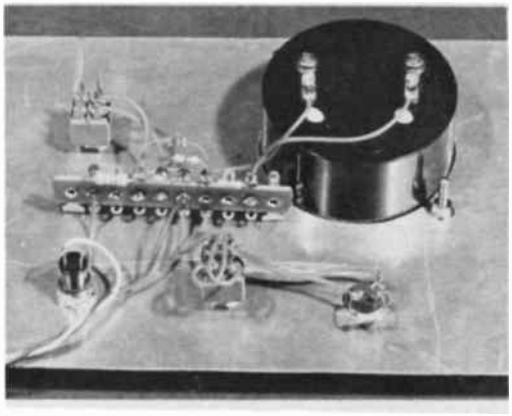
PARTS LIST — Transistor Tester — ETI 222

R3 Resistor 33Ω ½ watt 5%
R2 Resistor 270Ω ½ watt 5%
R1 Resistor 470Ω ½ watt 5%
R4 Resistor 470k ½ watt 5%
D1 Diode IN914
ZD1 Zener diode BZY88C5V6
SW1 Push button push-to-make
SW2 Switch toggle DPST
SW3 Switch toggle SPST
9V battery
M1 Meter 1mA movement
SK1 Socket T05 transistor type
Metal case or minibox

HOW IT WORKS

Operation of the tester is very simple. The meter, M1, monitors the collector current of the transistor under test whilst R4 supplies a current of about 10 μA into the base of the test transistor. Thus, on the 100β range, the maximum collector current will be 1 mA and, on the 1000β range, 10 mA. Switch SW3 therefore changes the meter sensitivity according to the beta range selected.

The meter is protected by means of D1 against damage due to test transistors being shorted. The zener diode ZD1 stabilizes the battery voltage to 5.6V.



The construction method may readily be seen from this photograph of the back of the front panel.

World Radio History

BATTERY CONDITION INDICATOR

Ever been caught by a battery that went flat at an embarrassing moment — like when you've just offered a friend a lift? The conversation goes a little flat when you're both riding the bus to work, 20 minutes late. Jonathan Scott found a solution . . .

THE OLD, RELIABLE lead-acid battery may be way ahead of what ever is in second place for vehicle electrical systems, but they do need a 'weather eye' kept on them. Particularly if they're out of warranty. The same applies to 'reconditioned' batteries, so often found in secondhand vehicles of some age.

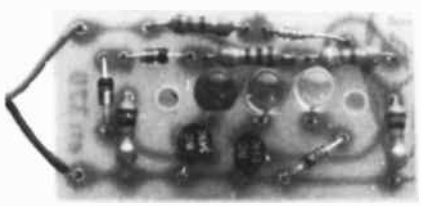
That's the problem with cars — running out of petrol and running out of battery produces the same heart-rending result. Immobility.

Most vehicles have a petrol gauge. Few have an equivalent for the battery. Many 'older' cars included a 'charging current' meter. This told you something about the car's generator-regulator and required some interpretation to figure out whether the battery was in good health.

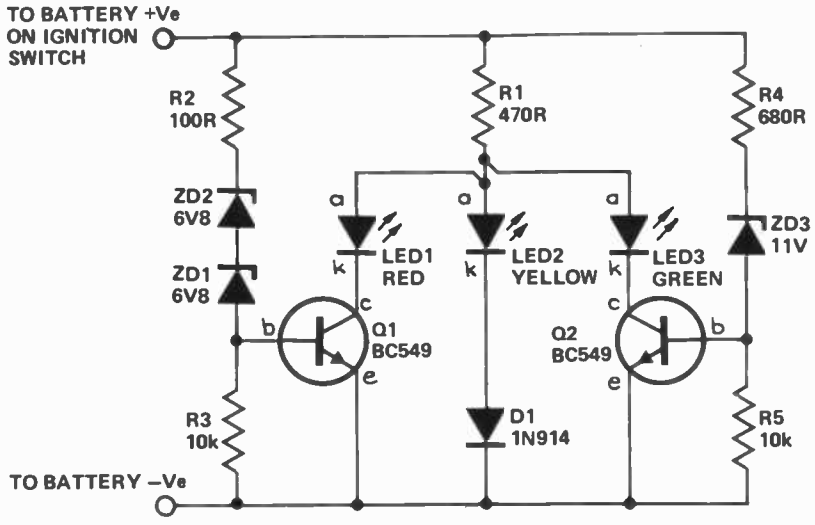
Probably the best way to check on the state of your battery is to use a hydrometer. However, hydrometers have a number of drawbacks. Being made of glass, they're fragile and can't be used while a car is in motion. The small amount of battery acid that remains on them presents a storage problem — the drips and fumes attack most metals and materials. They're okay for the corner garage but justifying their cost,for the occasional use they get in home workshops, is not always possible.

Another method of testing battery condition is by checking the voltage 'on load'. A lead-acid vehicle battery in a reasonable state of charge will have a terminal voltage under normal working load somewhere between 11.6 and 14.2 volts. When a battery shows a terminal voltage below 11.6 volts its capacity is markedly decreased and it will discharge fairly quickly. Like as not, it won't turn the starter motor for very long! On the other hand, if the voltage on load is above 14.5 volts then the battery is definitely fully charged! However, if it remains that way for any length of time while the car is on the road, the vehicle's alternator-regulator system is faulty and the battery may be damaged by overcharging.

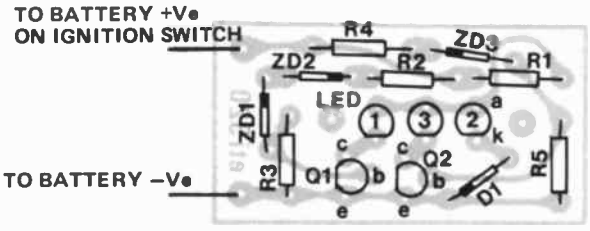
Reading the battery voltage can be done in a number of ways. You could use a digital panel meter, set up as a voltmeter. Their drawback is that they cost nearly ten times as much as a hydrometer! The next best method is to use an 'expanded-scale voltmeter'. Reading the voltage range between 11 and 15 volts on a meter face calibrated 0-16 volts is a squint-and-peer exercise. On a 0-30 volts scale, as used on many modern multimeters, it's worse. A meter which reads between 11 volts at the low end of the scale and 16 volts at the high end is ideal. Hence, the term 'expanded-scale'.



World Radio History



The circuit diagram and component overlay (below). During construction, make sure all of the diodes and LEDs are the right way round.



HOW IT WORKS – ETI 320

This circuit depends for its operation upon the different voltage drops across different colour LEDs.

At 20 mA the voltage drops across red, yellow and green LEDs are typically 1.7, 3.0 and 2.3 volts respectively. When the vehicle battery voltage is too low to cause either ZD1/ZD2 or ZD3 to conduct, Q1 and Q2 are held off by R3 and R5. Under these conditions the yellow LED is forward biased and conducts via D1 producing a potential of about 3.7 volts at point A (see circuit diagram). When the supply rises above about 11.6 volts ZD3 conducts, biasing Q2 on. By virtue of its lower voltage requirements the green LED conducts, reducing the voltage at point A to approximately 2.6 volts. This is not enough to bias D1/LED3 on, so the yellow LED goes off. The green LED 'steals' the bias from the yellow LED. When the supply rises above about 14.2 volts, Q1 is biased on and the red LED 'steals' the bias from the green. The potential at point A falls to two volts and only the red LED conducts.

R1 limits the current through the LEDs. R2 and R4 limit the base currents into Q1 and Q2.

PARTS LIST – ETI 320

Resistors all ¼W, 5%

R1	470R
R2	100R
R3, R5	10k
R4	680R

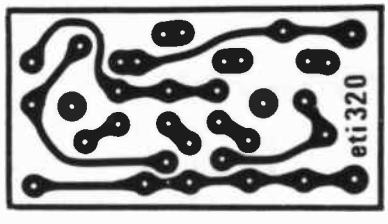
Semiconductors

D1	1N914
ZD1, ZD2	6V8 400 mW zener
ZD3	11V 400 mW zener
Q1, Q2	BC547,8,9 or BC107, 8, 9 or common silicon NPN type

Miscellaneous

pcb ETI 320

Aluminium angle bracket for under-dash mounting.



The printed circuit board pattern

However, you don't want to be peering at a meter on the dash board when you're driving through traffic. The range of voltage over which your battery is healthy is some two volts. An indicator which simply requires the occasional glance, and needs no 'interpretation', is what is really needed.

With this project, that's exactly what we've done.

Go, caution, stop

We have devised a simple circuit that indicates as follows:

Yellow:	battery 'low'
Green:	battery okay
Red:	battery overcharging

When the battery voltage is below 11.6 volts, a yellow indicator lights. This indicates the battery is most likely undercharged or a heavy load (such as high power driving lights) is drawing excess current. When it is between 11.7 and about 14.2 volts the green indicator lights, letting you know all is sweet. If the red indicator lights, as it will if the voltage rises above 14.2 volts, maybe the vehicle's voltage regulator needs adjusting or there is some other problem.

The circuit

The circuit is ingeniously simple, having barely a handful of parts. Reliability should be excellent.

We actually started out with a somewhat complex circuit. It used only two indicators and required you to 'interpret' what was happening. In trying to convert that to a yellow-green-red style of indication it sort of grew like topsy. This circuit had four transistors, a dozen resistors etc and didn't look at all attractive as a simple project that the average hobbyist or even handyman could build one Saturday afternoon and get going immediately. A rival circuit was devised by another staff member using a common IC. This sparked a controversy as to which was the better! Certainly, both did the job required . . . but maybe there was a simpler method.

It was discovered that different coloured light emitting diodes (LEDs), which we had decided to use for the indicators in the project, had different voltage drops when run at the same current. Seizing on this idea, the original circuit (four transistors, a dozen resistors . . .) was modified to exploit this characteristic and the simple circuit you see here was the result.

Construction

Construction is straightforward. If you haven't soldered electronic components

World Radio History

before – and this project was designed for the motorist/handyman as well as electronics enthusiasts – then we suggest you practice on something before tackling this project. Soldering is one of those things like swimming or riding a bicycle, or sex – it's okay once you've done it once or twice but you don't practice out on the street!

We recommend you use the printed circuit board designed for this project. The actual layout of the components themselves is not critical but a printed circuit board reduces the possibility of errors.

It is best to mount and solder the resistors first. Follow this by soldering in the diodes D1 and the zener diodes ZD1, ZD2 and ZD3. Carefully follow the accompanying component overlay making sure the diodes are all inserted the correct way around. Next, mount the transistors, again referring to the overlay, checking to see they are inserted correctly before soldering.

Finally, mount the light emitting diodes. These too may only be inserted one way. Check with the component overlay and connection diagrams. Make sure they are in the correct sequence. On the component overlay, LED 1 is the red LED, located at the left. The yellow LED is on the right, marked with a '2'. The green LED, marked '3' is between them.

The circuit could be tested at this stage if you have a variable power supply, or access to one. Simply vary the voltage across the range between 11 and 16 volts and note whether the LEDs light up in the correct sequence and close to the voltages indicated.

Mounting

As vehicles vary so much in dash panel layout, we can only make general suggestions.

Clearly, the indicator should be mounted such that the three LEDs are not in direct sunlight. A low part of the dash, but make sure it's readily visible from your normal driving position, will pretty well ensure the display may be easily read during the daytime. Alternatively, if you have an 'overhung' dash, or a portion which overhangs (usually where the instruments are mounted anyway), then a suitable position will generally suggest itself.

Exact mechanical details will have to be determined according to your particular situation. Two holes are provided in the pc board for mounting bolts. Alternatively, the whole assembly may be mounted from the LEDs. Three LED holders inserted through part of the dash panel, or an escutcheon plate mounted on the dash, will hold the LEDs quite securely. Providing the leads on the LEDs are fairly short, the pc board will place little strain on them and the assembly should be mechanically secure.

Connection

The indicator may be installed in vehicles having positive or negative earth electrical systems.

The component overlay shows the connection for a negative earth vehicle. The 'battery +ve' lead goes to the ignition switch – the indicator only operates when the vehicle is being used – the battery negative lead should be taken to a good 'earth' point on the vehicle frame.

For a positive earth vehicle, the lead marked 'battery –ve' goes to the ignition switch connection, while the 'battery +ve' lead goes to the vehicle frame.

DEAD OR ALIVE?
WHEN YOU NEED TO KNOW
DON'T TAKE CHANCES!
The non-contact EZ-Scan unit gives an immediate visual indication of voltage, with or without current flowing at distances up to 10" away from the source.
Battery powered and all solid state, the unit is small enough to be carried in a pocket, tough enough to live in a tool box.
To find a break in a cable, a bad earth, a faulty fitting or just to know if it's live — use the EZ-Scan. For all unshielded a.c. electrical systems, 60 V and higher.
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World Radio History

Microwave ovens sure have lots of zip, but don't get zapped! Build our —

Microwave oven leak detector

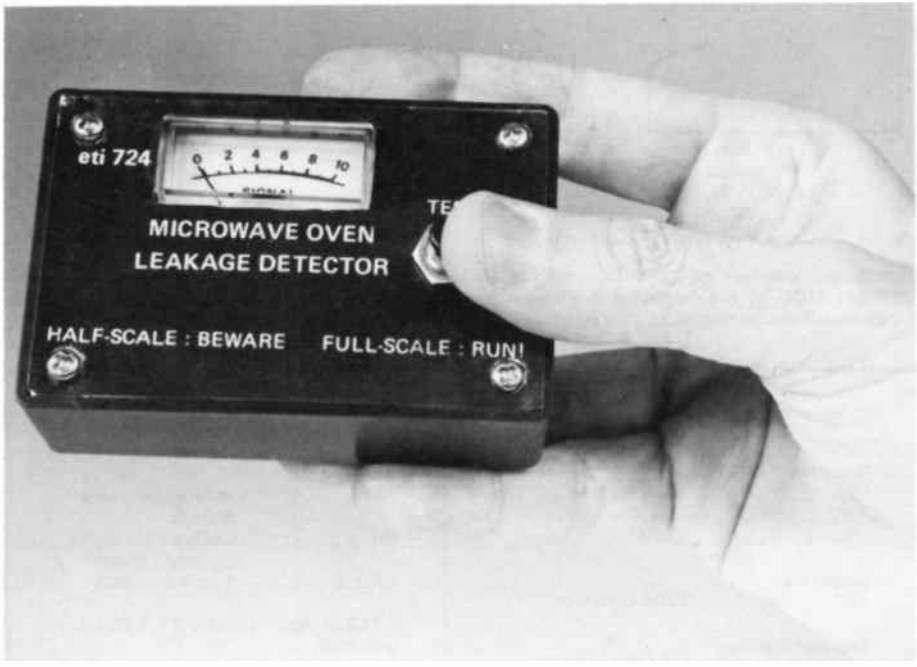
While microwave ovens are generally well-designed and safe to use, the human factor (even Murphy's Law) can thwart the manufacturer's efforts and possible unsafe levels of microwave energy may be radiated without warning. Simple and inexpensive to build, this project will indicate if your oven is safe . . . or not.

Jonathan Scott

THE MICROWAVE oven is one of the most recent examples of advanced technology finding application in the home. Many thousand such devices are sold for domestic use in Australia alone each year, while commercial units have long been found in restaurants and snack-bars.

The microwave cooking method, while unlikely to usurp conventional cooking methods, has distinct advantages. It is usually quicker; two to five times quicker in fact. Because it heats the foods directly, but does not heat the bowl or container, the food can be left enclosed. The process is often cleaner and less utensil-consuming as a result. Because the energy penetrates below the surface of a lump of food and does not rely so completely on conduction, it can be used for rapid defrosting of foods. (See "How a microwave oven works").

Unfortunately, the microwave energy is quite dangerous. It must be carefully contained within the cooking chamber. The window is usually sealed to the radiation by a fine metal grille similar to heavy duty fly-screen. The door fits flush and firm, and the instructions warn against allowing any distortion of



The device is housed in a 'zippy' box, everything being attached to the front panel, held in place by the four screws. Our prototypes were calibrated through the kind assistance of the Electrical Engineering Department of Sydney University.

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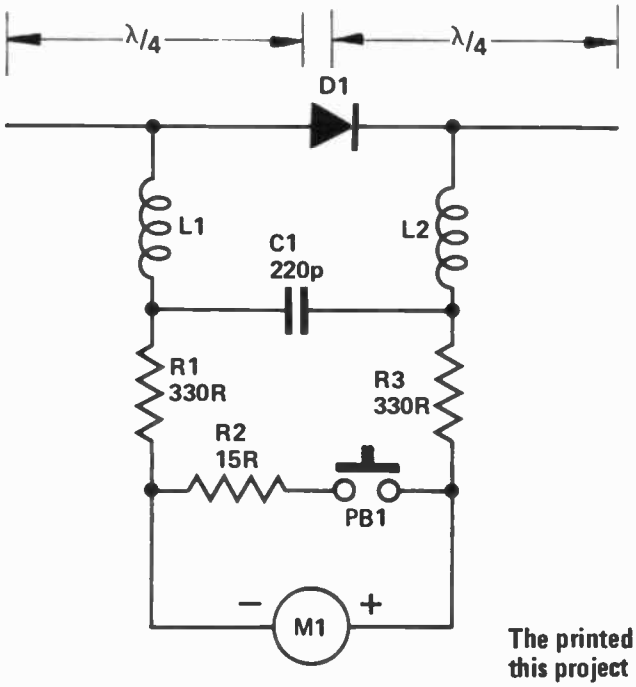


The printed circuit board artwork for this project is on page 128.

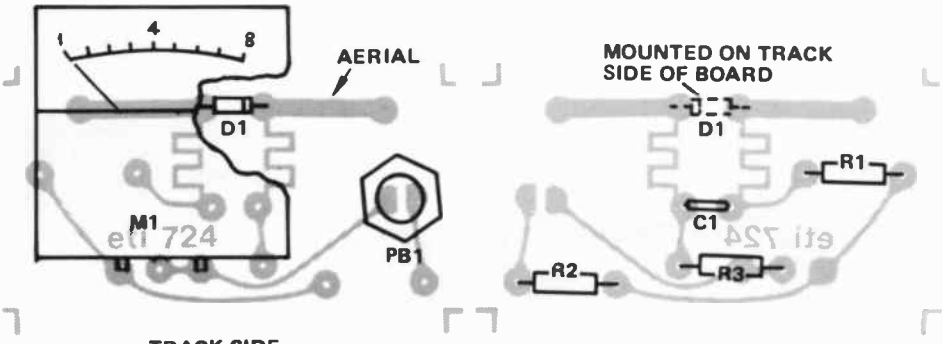
HOW IT WORKS – ETI 724

Operation is very simple. The device is completely passive and requires no batteries. It uses the radiated energy from the oven to deflect a meter directly.

The pc board dipole, when exposed to microwave radiation of about 2.5 GHz, develops an ac voltage across D1. When the diode is positively biased the diode conducts, shorting the dipole. When reverse biased it isolates, thus leaving a net voltage on the diode. This DC component is filtered by L1, L2 and C1.

The amplitude of the dc component varies somewhat with the type of radiation from the oven – CW or pulsed, depending upon the supply rectification and filtering used with the magnetron. It will also vary with distance, of course. The Australian safety limit is 5 mW/cm^2 at a distance of 5 cm from the oven. R1, R2 and R3 define the sensitivity, the values chosen being suitable to produce FSD for 5 mW/cm^2 CW at the pc board plane with PB1 closed.

Some variation should be expected from unit to unit. This should not normally be of any concern, however, as a healthy oven will emit at least one order of magnitude less than the 5 mW level, and so the readout is unambiguous even when the unit is not the exact 5 cm from the oven surface.



Component overlays of both sides of the pc board. Note that the diode is mounted on the COPPER SIDE of the board. It is strongly recommended that the device is constructed using the pc board design shown so that results are consistent with the calibrated prototype.

PARTS LIST - ETI 724

Resistors
R1 . . . . . 330R
R2 . . . . . 15R
R3 . . . . . 330R

Capacitor
C1. . . . . 220p ceramic

Semiconductor
D1 . . . . . HP 5082–2800 Shottky Hot Carrier Diode

Miscellaneous
PB1. . . . . momentary push button
M1 . . . . . 250μa FSD Signal Strength meter
L1, L2 . . . . . Etched on pcb

ETI 724 pcb (includes L1, L2 and antenna).

Plastic jiffy box (25 mm x 50 mm x 90 mm).

the door. All ovens have safety circuits preventing the power being applied with the door open. Some ovens have as many as five interlocks against accidental activation without correct door closure. They do not, unfortunately, incorporate an alarm which warns if a leak occurs. This can happen if the door is slightly bent by being closed on a lump of stray food or if damaged during a domestic fracas.

In view of these things it seems wise to have some additional method of checking for leakage.

Leak detectors

There are some commercial leak detectors available. The most common one is made by the CSIRO. This consists of some circuitry, including a LED, encapsulated in a clear plastic tube. Entirely passive in operation, it illuminates the LED if the integral 62 mm long dipole is exposed to radiation of approximately the safe recommended limit. The CSIRO device is the cheapest available and sells for around $15. In operation it is satisfactory, but has two drawbacks. Firstly, were the hot carrier diode to be destroyed, as could happen for any number of reasons, including being exposed to cook strength signal, a 'safe'

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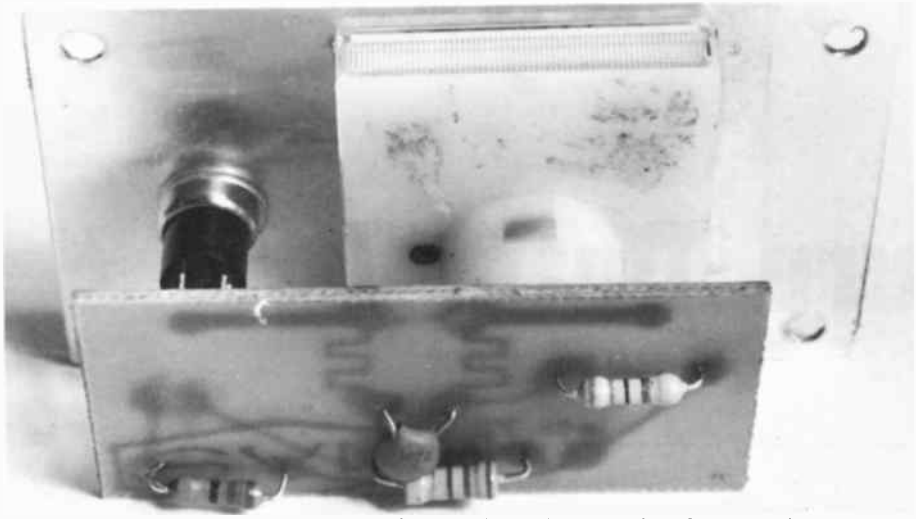


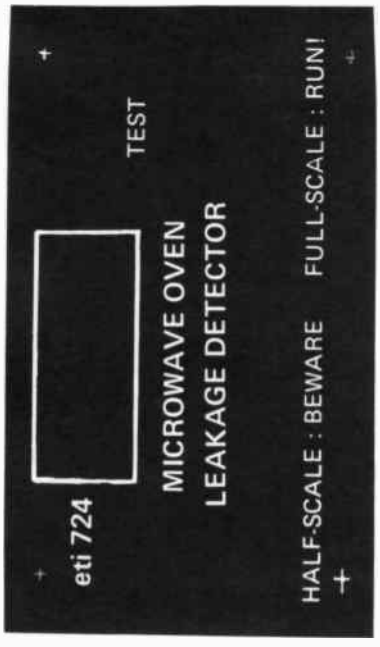
Internal view of the microwave oven leak detector shows the simplicity of construction.

report would always be given. In other words, the device cannot easily be checked. Secondly, the output is go/no-go. No indication of gradual increase in leakage is available.

So, if leakage from your oven has been gradually getting worse, you won't know until it reaches the level that trips the sensor (admittedly this may still be well below the harmful level).

Our design does not suffer from these drawbacks. The output is an analogue meter. This is set to read full-scale deflection (FSD) for a signal of approximately 5 mw/cm^2 in the 'test' mode. Hence, as little as 10% of the danger level can be read.

When the test button is released, the sensitivity increases by about an order of magnitude. In this condition the unit acts like a signal strength meter, and should show some deflection with the normal residual leakage of an oven. This confirms that it is working. We estimate that it should cost $10-$12, pc board included, as a kit. If you have upwards of $300 worth of oven, ten dollars is not a bad investment to insure the family jewels . . .



Construction

Unless you are very experienced with high frequency work already it is important to use the pc board. The antenna is printed onto the board and so, is inherently tuned sufficiently closely when the correct board is used. It is also convenient as the meter and button are soldered directly on the copper side and the whole assembly is self-contained.

No box at all is actually necessary, but if you choose to use one, ensure that it is not metallic except for the front panel. There are no flying leads, etc, so if need be, one could leave the whole circuit just as is, with no box.

We used a 25mm x 50 mm x 90 mm jiffy box which was just big enough inside.

Ensure that the diode and meter are soldered in the right way round. Also try to solder the diode neatly, as shown in the overlay. It should be soldered onto the copper side directly, flat against the pc board in the centre of the dipole. Use of the board and close adherence to our design will ensure that your unit is close to prototype sensitivity and will thus read true.

Using it

The meter is moved around the door rim with the oven operating, meter facing away, button depressed, the back parallel to the door and spaced approximately 40 mm from the surface.

When testing, it should be moved over the oven in each polarisation, just to be sure. To check if it is working, simply repeat the procedure without depressing the test button. Some erratic flicker of the needle should be evident, indicating correct operation. It can be left on top of the oven when not specifically being used, so that some drastic leak will cause deflection should that occur.

How a microwave oven works

There are several separate sections to a microwave oven. Firstly, there is a Magnetron, which is the heart of the system. This is a thermionic device incorporating a resonant cavity. It is an oscillator and will deliver power at super high frequencies (microwave ovens operate on 2.45 GHz). The oven has a power supply incorporating a number of safety interlocks preventing activation in unsafe circumstances.

There is a cooling system for the electronics, usually a fan. The cooking chamber has metal walls and some system of ventilation to remove steam, etc. The one fan is often used to cool the electronics as well as ventilate the cooking chamber. A duct (waveguide) transfers the microwave energy to the chamber from the magnetron. Some form of disperser spreads the energy and prevents standing waves within the chamber. This is either a rotating platform moving the food or a set of vanes in the chamber ceiling reflecting the beam about. (This is often driven by the fan motor or even the stream of cooling-ventilating air).

Finally, a control panel allows varying degrees of automatic control of the RF power. This always includes a timer and a door interlock.

Water is the primary microwave absorbing agent in food. Dry food and glass or plastic containers are substantially unheated by the radiation. The energy can penetrate to a depth of about 20 mm effectively, though this varies markedly with the food.

Domestic ovens consume about 1200 watts altogether, of which about half appears as microwave power in the food chamber. This, considering the mode of absorption, is considerably more efficient than an ordinary oven which is why the cooking speed is so rapid.

World Radio History

Digital Temperature Meter

This simple yet accurate temperature meter will find many uses in the laboratory or home. It utilizes the digital panel meter described on page 23.

THE RELIABILITY OF electronic circuits in the days of valves was, to say the least, poor by today's standards. The introduction of transistors and integrated circuits increased reliability dramatically. One of the main reasons for this is the reduction of power dissipation and the resultant lowering of temperature. Devices and circuits are now designed to minimise power dissipation as this allows a higher component density while increasing reliability. However some circuits by their nature must dissipate high power and the semiconductor devices used must be kept within their temperature limits.

This temperature meter will allow transistor temperatures to be measured and the appropriate heatsink chosen. It is just as useful outside the electronic scene measuring liquid or gas temperature especially where the readout needs to be physically separate from the sensor.

Use and Accuracy

The accuracy of the unit depends on the calibration; provided it has been calibrated around the temperature at which it will be used, accuracy of 0.1 degree should be possible. We could not accurately check linearity but it appeared to be within 1° from 0° to 100°C.

However other errors will affect this reading. If measuring the surface temperature i.e. a heatsink temperature, there will be a temperature gradient between the surface and the junction of

World Radio History

SPECIFICATION – ETI 589

Temperature range	– 50°C to +150°C – 60°F to +199.9°F
Resolution	0.1°C or F
Sensor	silicon diode
Power consumption	1.5mA @ 9 V dc

the diode. Silicon grease should be used to minimise the surface-to-surface temperature difference. Also when measuring small objects, e.g. a TO-18 transistor, the probe will actually cool the device slightly. At high temperatures these effects could give an error of up to 5% (the reading is always less than the true value). If the probe is in a fluid, e.g. water or air this problem does not occur.

Construction

Assemble the panel meter as previously described but omitting the zener diodes and R6 and R7. The value of R1 has also been changed. The decimal point drive should be connected to the right-hand decimal point. The additional components can be assembled on a tag strip as shown.

We mounted our unit on a tag strip as shown in the photo. While we have not given any details, knocking up a case should be no problem. For a power supply we used eight penlight Nicad cells giving a 10 V supply. If dry batteries are used six penlight cells are recommended although a 216-type 9 V transistor battery will give about 300 hours of operation.

The sensor should be mounted in a probe as shown in Fig. 1 if other than air temperature will be measured. This provides the electrical insulation needed for working in liquids etc. It should be noted however that the quick dry epoxies are not normally good near or above 100°C and if higher temperatures than this are expected one of the slow dry epoxies should be used.

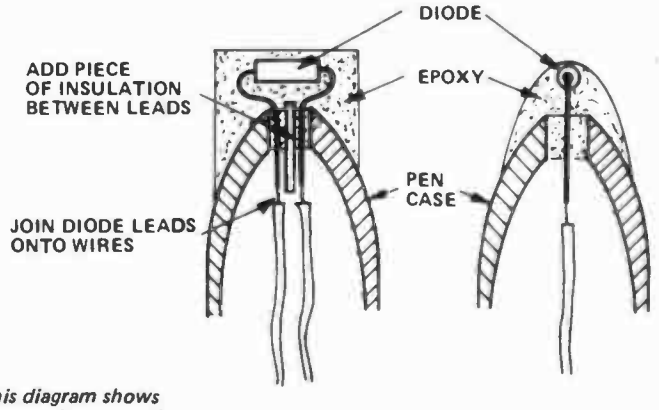


Fig. 1. This diagram shows how the sensor is mounted into a ball-point pen casing or similar.

Calibration

To calibrate this unit two accurately known temperatures are required, one of which is preferably zero degrees and the second in the area where the meter will normally be used and highest accuracy is required. For a general-purpose unit 100°C is suitable. The easiest way of obtaining these references is by heating or cooling a container of distilled water. However temperature gradients can cause problems, especially at zero degrees.

One method of obtaining water at exactly zero degrees is to use a test tube of distilled water in a flask of iced water and allowing it to cool to near zero. Now by adding salt to the iced water its temperature can be lowered to below zero. If you are very careful, the test tube water will also drop below zero without freezing (you should be able to get to about -2°C). However the slightest disturbance at this temperature will instantly cause some of the water to freeze and the remaining water to rise to exactly zero, providing an ideal reference.

For a hot reference the boiling point of distilled water is very close to 100°C especially if the container has a solid base and is evenly heated e.g. on an electric hotplate.

The actual calibration is done as follows:

1. In the 0°C reference adjust RV2 and RV3 until the unit reads zero.
2. In the hot reference adjust RV1 to give the correct reading.

This should be all the adjustment required.

If zero degrees is not available, e.g. if setting up for °F, the following method can be used:

1. In the cold reference use RV2 and RV3 to adjust reading to zero.
2. In the hot reference use RV1 to adjust the reading to indicate the temperature difference between the two standards. If freezing and boiling points are used, this will be 180°F.
3. Now, back in the cold bath, adjust RV2 and RV3 to give the correct reading.

No further adjustment should be required.

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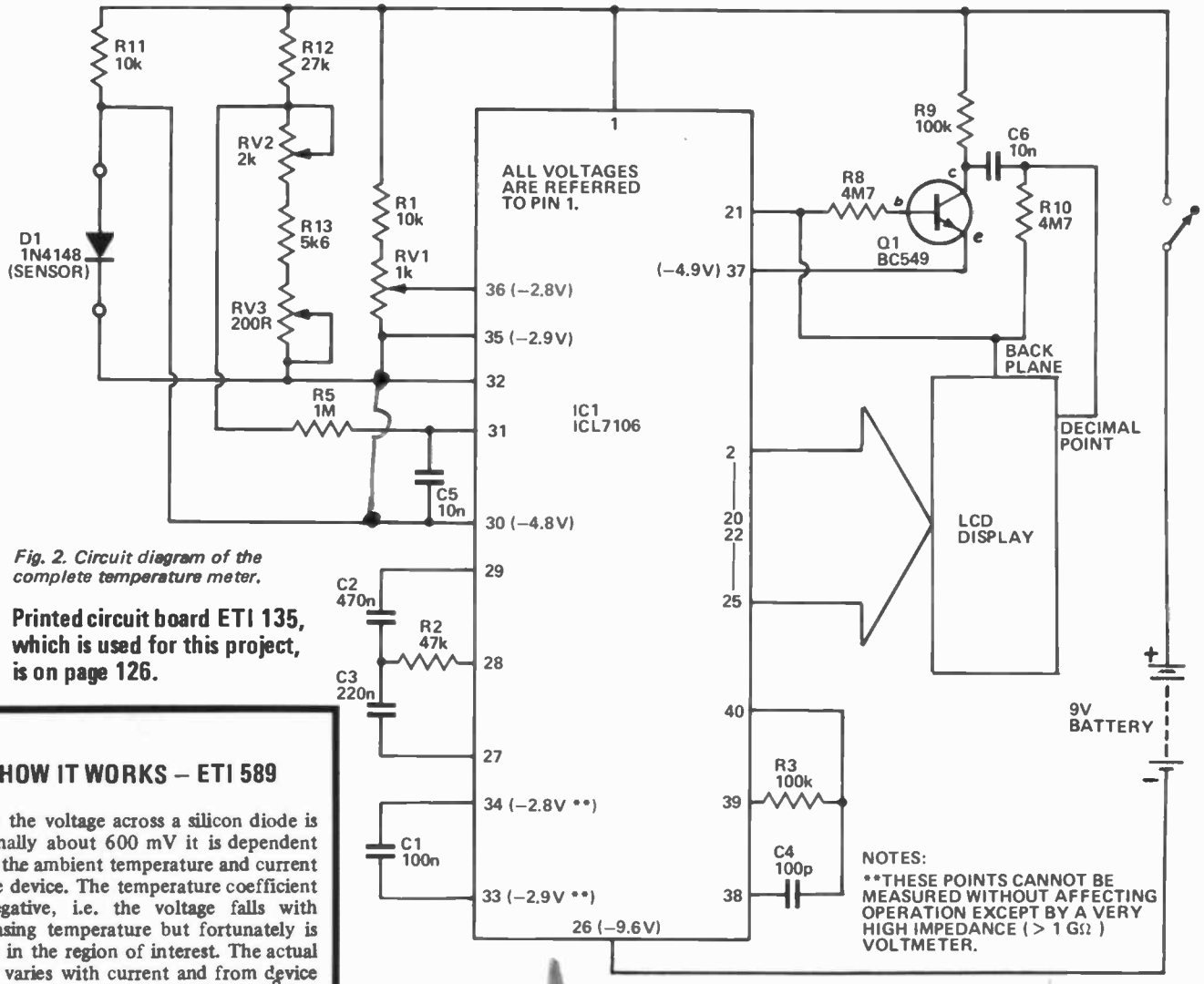


Fig. 2. Circuit diagram of the complete temperature meter.

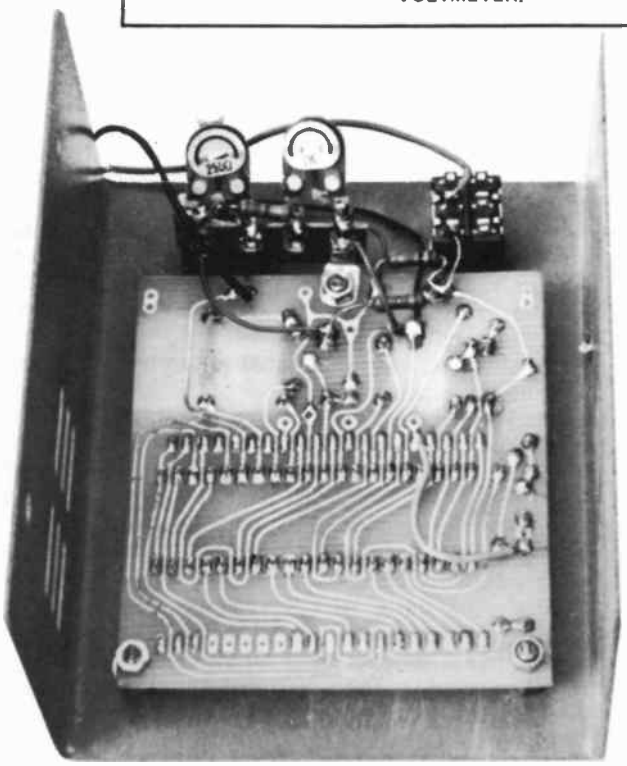
Printed circuit board ETI 135, which is used for this project, is on page 126.

HOW IT WORKS – ETI 589

While the voltage across a silicon diode is nominally about 600 mV it is dependent upon the ambient temperature and current in the device. The temperature coefficient is negative, i.e. the voltage falls with increasing temperature but fortunately is linear in the region of interest. The actual value varies with current and from device to device, but is typically −2.2 mV/°C at 250 μA.

By measuring the voltage across the diode with a suitable offset voltage to balance the voltage at zero degrees an accurate temperature meter results. The digital panel meter described on page 23 has a stable reference voltage available (between pins 1 and 32) of about 2.9 V; with the 10k resistor R11 this provides a constant current for D1 (the sensor). The offset voltage is also derived from this reference voltage by R12, RV2 and RV3. The panel meter is used as a differential voltmeter and measures the potential difference between the offset voltage and the diode. We have used two trimpots in series in the offset adjustment to give better resolution. If desired a 10-turn trimpot can be used (2k2). Adjustment of the three potentiometers allows the meter to be calibrated in either °C or °F with the upper limit of 199.9°F due to the panel meter over-ranging.

The power supply is simply a 9 V battery, and so the zener diodes and dropping resistors described in the panel meter article should be omitted.



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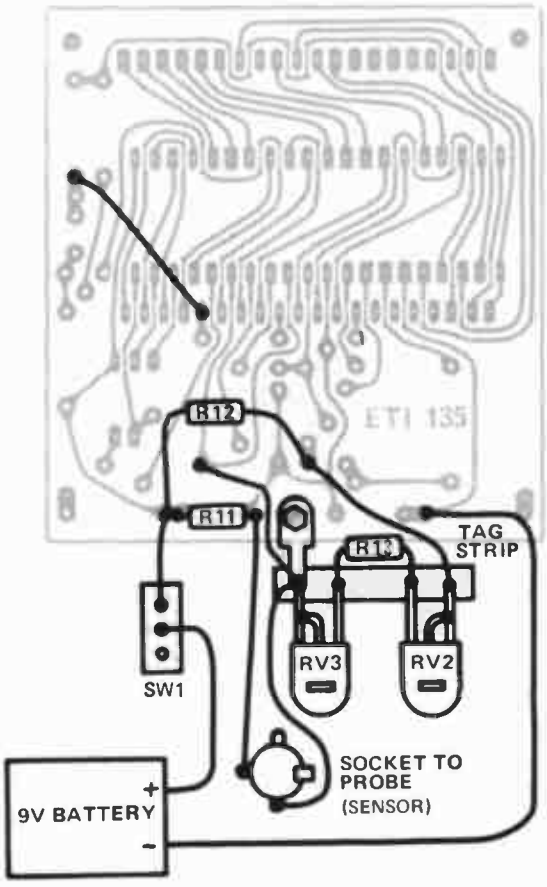


Fig. 3. The external components associated with the panel meter. For details of the panel meter see Project 135, page 23.

PARTS LIST – ETI 589

Resistors all ½ W, 5%
† R1 . . . . . 10k
* R2 . . . . . 47k
* R3 . . . . . 100k
R4 . . . . . not used
* R5 . . . . . 1M
R6 . . . . . not used
R7 . . . . . not used
R8 . . . . . 4M7
R9 . . . . . 100k
R10. . . . . 4M7
R11. . . . . 10k
R12. . . . . 27k
R13. . . . . 5k6

Potentiometer
* RV1 . . . . . 1k 10 turn trim
RV2 . . . . . 2k trim
RV3 . . . . . 200 trim

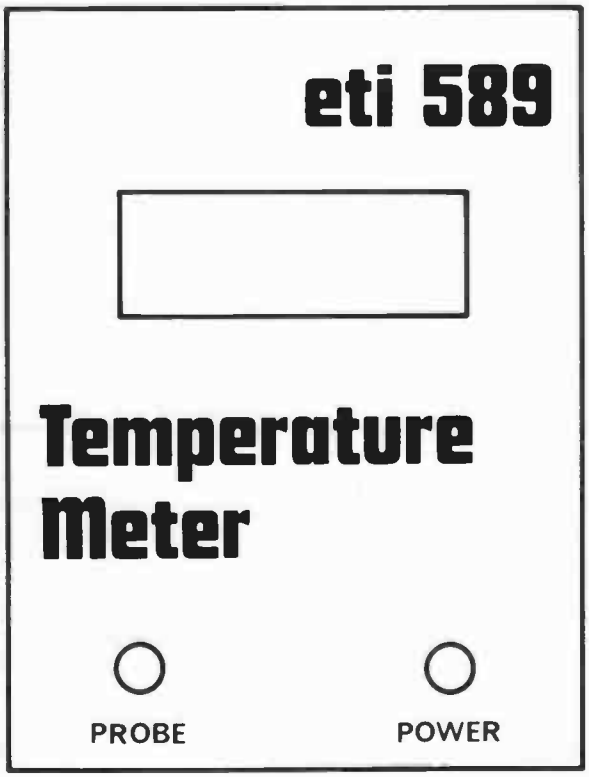
Capacitors
* C1. . . . . 100n polyester
* C2. . . . . 470n "
* C3. . . . . 220n "
* C4. . . . . 100p ceramic
C5. . . . . 10n polyester
C6. . . . . 10n "

Semiconductors
* IC1 . . . . . ICL7106
Q1 . . . . . BC549
D1 . . . . . 1N4148

Miscellaneous
PC board ETI 135
Tag strip
* LCD Display
* Socket for LCD display
Box
Switch
9V battery

* These components are supplied with the Intersil ICL7106 EV evaluation kit.

† This value has been changed from the original panel meter.



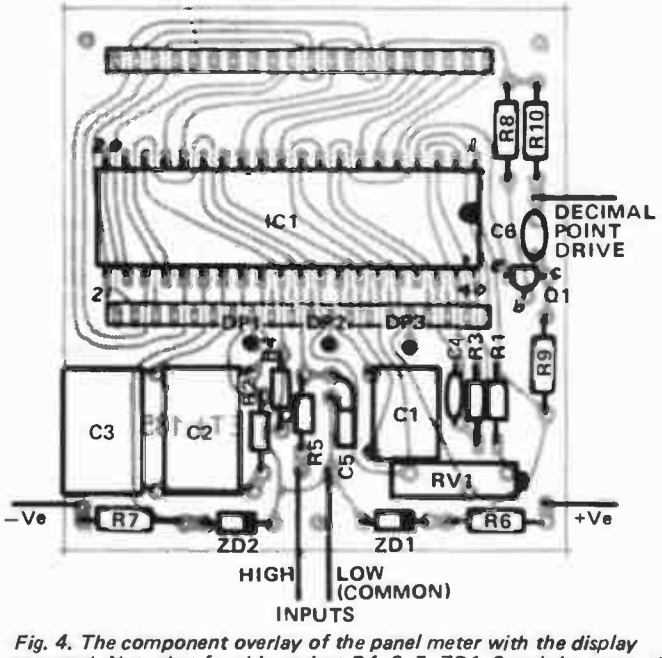


Fig. 4. The component overlay of the panel meter with the display removed. Note that for this project R4, 6, 7, ZD1, 2 and the external leads are not used.

World Radio History

DIGITAL STOPWATCH

When we couldn't get hold of a stopwatch chip that would do the things we wanted, we designed our own stopwatch from scratch. . .

THE SURVEY we conducted last year on the requirements for a sports timer revealed a requirement for, basically,a good stopwatch. As most stopwatches are used in outdoor sports, it is not really practical to use an LED display. The power requirement of this type of display, if it is to be seen in daylight, is very high for portable use. We therefore decided to wait for the appearance of economical LCD displays before commencing our design.

While the stopwatch described here is not particularly small, it can be easily hand held, and uses a large display which is easily readable 3 - 4 m away, even in strong daylight. It can easily be remotely operated, either by mechanical switches or electronic control circuits.

SPECIFICATION – ETI 590

Display	6 digit LCD, 12.5 mm high
Maximum reading	59 minutes 59.99 seconds
Resolution	0.01 seconds
Readability	Up to 5 metres in dim light bright sunlight
Accuracy	Can be calibrated– crystal controlled
Modes	Normal, lap and total
Size	140 x 57 x 32 mm
Battery	9 V (216)
Battery life on off	 1 to 2 months shelf life

Design Features

The display we are using is a large (12 mm high) six digit liquid crystal unit. We chose a resolution of 0.01 s, giving a maximum display of 59 min, 59.99 s. We looked around for a single IC which would do all the work, but the only devices we could locate are designed for LED displays. Driving an LCD display usually requires an ac signal with an average dc component across the display of zero. This requirement prevents the display multiplexing as used in most special stopwatch ICs.

The low power consumption of the display indicated that CMOS should be used in the design, thus keeping the total supply current to less than 750 μA.

When deciding what stopwatch modes to provide, we were limited by the package count, as we are using standard CMOS ICs and not a custom LSI chip. We finally settled on the three commonest modes using a single memory.

Initially we did not think that a power switch would be necessary, but the supply current was higher than we expected, giving only about two months continuous use. We also originally used a slide switch to set each of the three modes, but the cost of these two switches and the space required made us look for an alternative method.

To delete a power switch, the supply current has to be reduced to less than 10 μA, so by checking where the 750 μA was going we found that the biggest power consumption was in the 4060 oscillator. Stopping the oscillator

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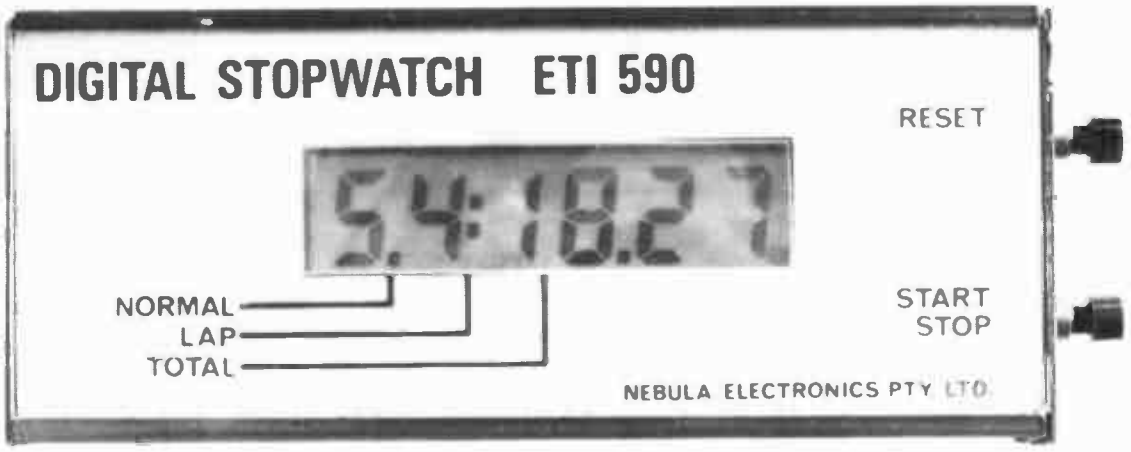


dropped the current but as the output of this IC drives the backplane of the display, stopping it will cause damage to the display.

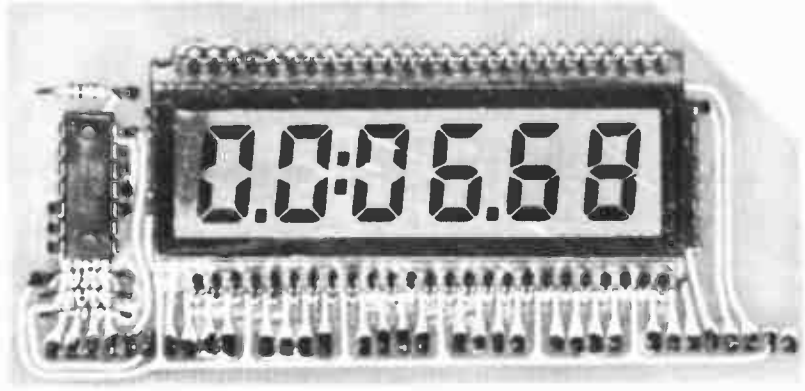
The method we chose for on/off switching was to remove power to all but three of the ICs in the off mode. To replace the mode switch we used analogue switches and three of the unused decimal points as indicators. Mode selection is performed by holding the reset button pressed while pushing the start/stop button. In the 'fourth' mode, two decimal points will come on, and if both buttons are released the display will turn off. Holding the button closed will turn off. Holding the reset button closed will bring the display back and pressing the start/stop button will move it into mode one.

Calibration

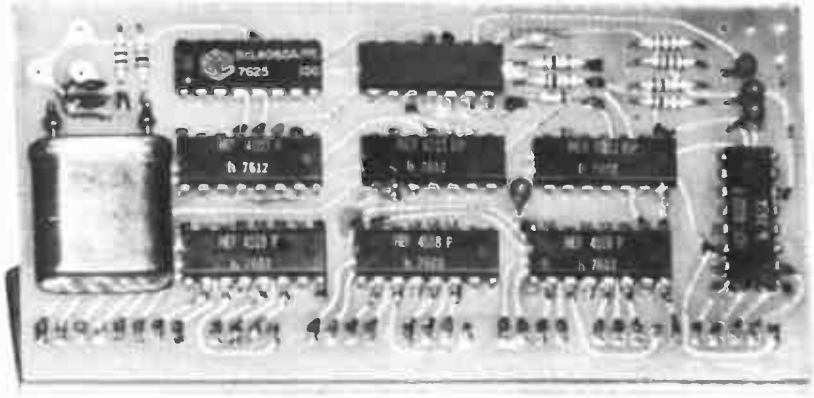
For normal use this is not required and a 33p capacitor is used for C2. Our prototype was about 0.1s slow in one hour. If greater accuracy is required CV1 can be used along with a 15p capacitor for C2. If so check the time over a one hour period, record the error, then turn CV1 slightly one way and recheck. Continue until the accuracy is within your limits. Due to the manual operation of the pushbuttons the longer the timing period the more accurate will be the calibration.

External operation

As the watch is simply operated by normally open pushbuttons any number can be paralleled or the leads extended. If electronic operation is required it is preferable that the output stage of that unit be open circuit NPN transistors. If an external voltage pulse is used, it should be between 6 and 9 volts high. It may be necessary to remove or reduce C3 and C4. Remember when designing your interface that the output should normally be high and the timing occurs on the negative going edge.



The unit with the display board in position.



The logic / control card.

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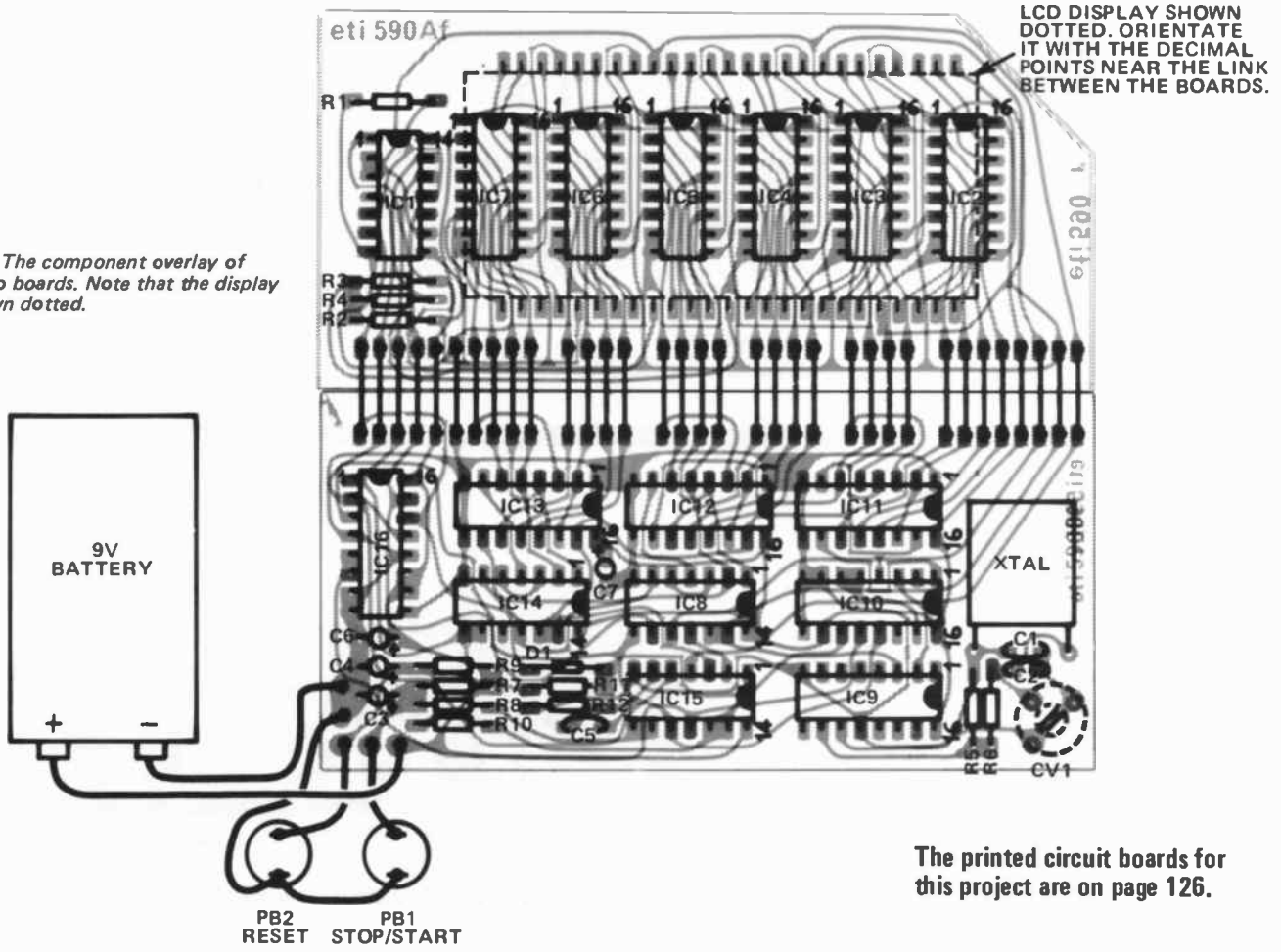

Fig. 2. The component overlay of the two boards. Note that the display is shown dotted.

The printed circuit boards for this project are on page 126.

PARTS LIST – ETI 590

Resistors all ¼W, 5%
R1–R4 . . . . 100k
R5 . . . . . 4M7
R6 . . . . . 1k
R7 . . . . . 47k
R8 . . . . . 1k
R9 . . . . . 47k
R10. . . . . 1k
R11, 12 . . . 100k

Capacitors
* C1, 2 . . . . . 33p ceramic
C3, 4 . . . . . 1μ0 tantalum
C5. . . . . 330p ceramic
C6, 7 . . . . . 1μ0 tantalum

Variable Capacitor
* CV1 . . . . . 2–30p trim (optional)

Semiconductors
IC1 . . . . . 4016 quad switch
IC2–IC7 . . . 4056 decoder
IC8 . . . . . 4011 two input NAND
IC9 . . . . . 4060 oscillator-divider
IC10 . . . . . 4027 J K flip flop
IC11–IC13 . 4518 dual decade counter
IC14 . . . . . 4011 two input NAND
IC15 . . . . . 4093 quad schmitt trigger
IC16 . . . . . 4027 J K flip flop
D1 . . . . . IN914 diode

Miscellaneous
PC boards ETI 590A, 590B
LCD display (Hamlin 3918 315)
Two push buttons
Batteryclip
Case to suit

*If CV1 is used reduce C2 to 15 pf.

Construction

With a circuit of this complexity it is virtually essential that the pcbs be used. These boards are double sided and many components have to be soldered on both sides. As a result, sockets cannot be used on the ICs (not that there's room for them anyway!). A small soldering iron with a fine tip is needed to solder the IC pins on the top of the board.

Before starting assembly, inspect the pc boards for any breaks or unwanted joins in the tracks as they are thin in places and it will be difficult to find a break later if it is under an IC! Start assembly with the display board (ETI 590A) inserting the ICs first and soldering them in. Ensure that they are oriented correctly and that they are sitting as close as possible to the pc board. It is recommended that the soldering iron tip be earthed to prevent damage to the ICs. After soldering the ICs in on both sides add the resistors and solder them in.

Now carefully examine the board for any bad solder joints before proceeding. The display is now added (do not remove the protective cover yet) such that it sits over the top of the ICs with the decimal points closest to the connector (the as yet unused row of holes along the edge of the board). The segments of the display can be seen if it is held at an angle to the light. The display should be sitting right on top of the ICs, as the leads are not too long. It should now be soldered into this position – be careful as the display is glass, and is both delicate and expensive!

The second board can now be assembled similarly. Glue a small (about 20 mm square) piece of thin card on to the pc board to insulate it from the crystal, before gluing the crystal into position.

For normal use, the crystal frequency is probably accurate enough with simply a 33 pF capacitor for C2. The prototype was within 0.1 s over a one hour timing period. The crystal can be trimmed by reducing C2 to 15pF and adding CV1. This adjustable capacitor is fitted to the *non*component side of the board and the corner of the display board is cut off to provide clearance for it.

The two boards can now be joined together by sitting them back to back, separating them by 7 - 10 mm, then 'sewing' them together with a long piece of tinned copper wire (see photo). Now

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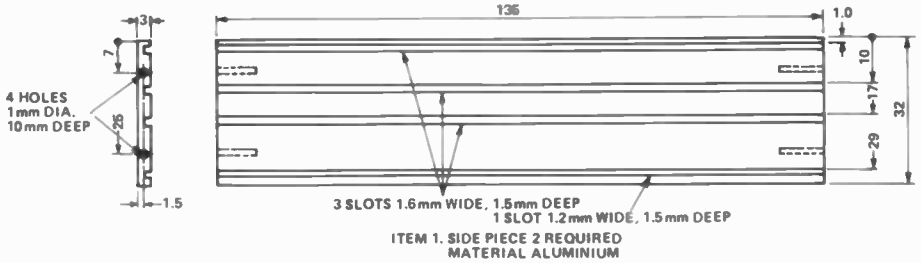
solder these links on the front surface of the display board, and bend the two boards apart to enable the three pads which are used to be soldered. Before soldering the control board on, the boards must be spaced correctly. This can be done by using the two side pieces of the box as a guide. Only the component side of the control board need be soldered. Once the boards have been soldered the excess leads can be cut off. The battery clip can now be connected along with the pushbuttons.

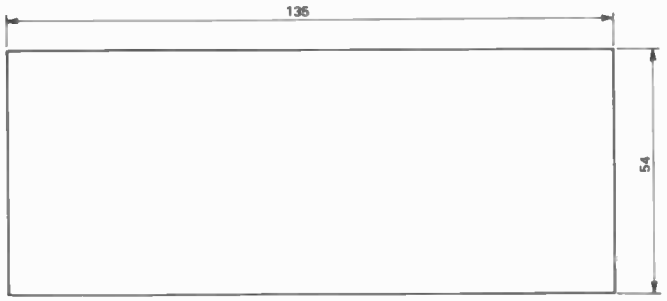
The operation of the unit can now be checked. When the battery is first connected the display may or may not come on depending on the mode. Pressing either button should bring the display on and it should be possible to step through the modes using the start/stop button while holding the reset button closed. Check that the unit operates in each mode.

The case can now be assembled. The case can be etched slightly in a caustic soda solution if desired, and then painted to give a good finish.

Note: An improvement in operation of the oscillator can be obtained by reducing R6 from 1 k to 100 ohms. If non-microswitch type pushbuttons are used, add a 1μF capacitor between pin 8 (+ve end) and pin 7 of IC15.
To prevent contact bounce, add a 1 μ tantalum capacitor between pins 7 and 8 of IC15 +ve and pin 8.
It may be necessary to reduce R6 to 100 ohms to ensure the crystal starts oscillating.

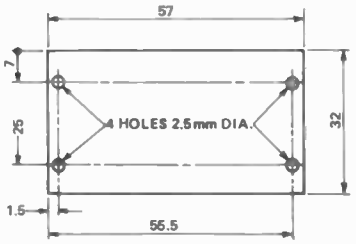


ITEM 1. SIDE PIECE 2 REQUIRED
MATERIAL ALUMINIUM

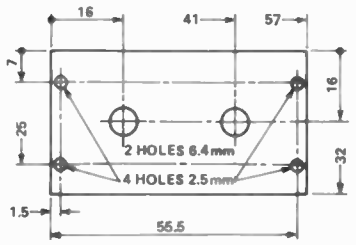


ITEM 2. BASE – MATERIAL ALUMINIUM
ITEM 3. WINDOW – MATERIAL 1.6mm PERSPEX

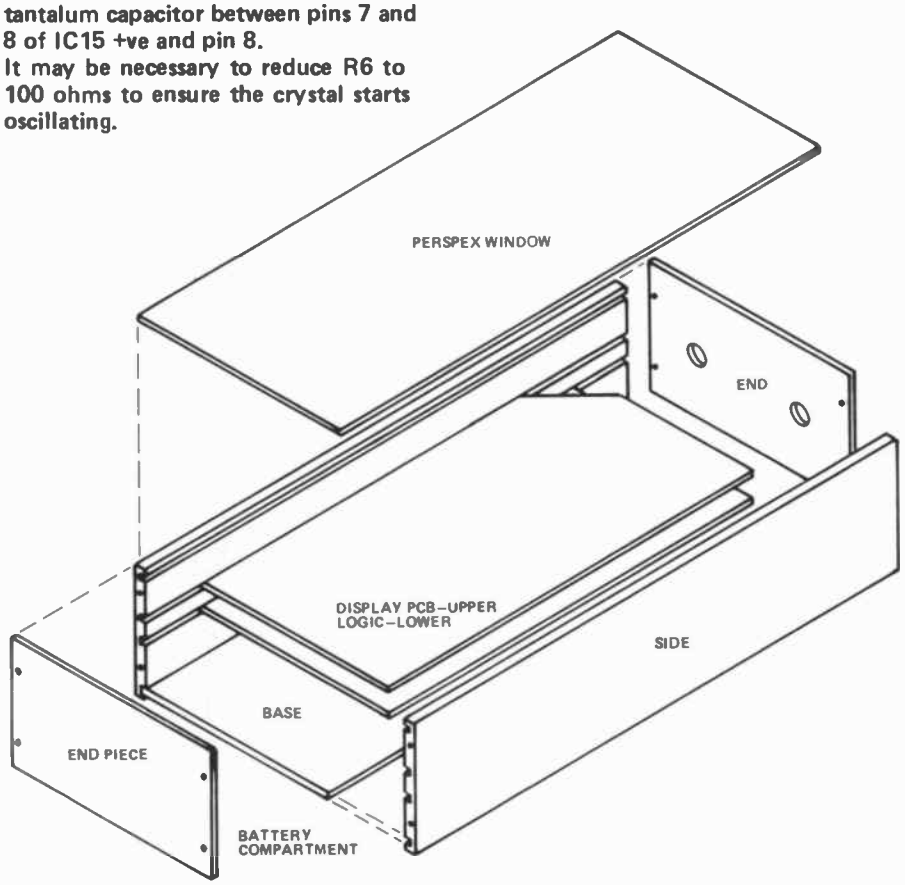
Fig. 3. The details of the metalwork used for the prototype.



ITEM 4. END PIECE – MATERIAL 1mm ALUMINIUM



ITEM 5. END PIECE – MATERIAL 1mm ALUMINIUM



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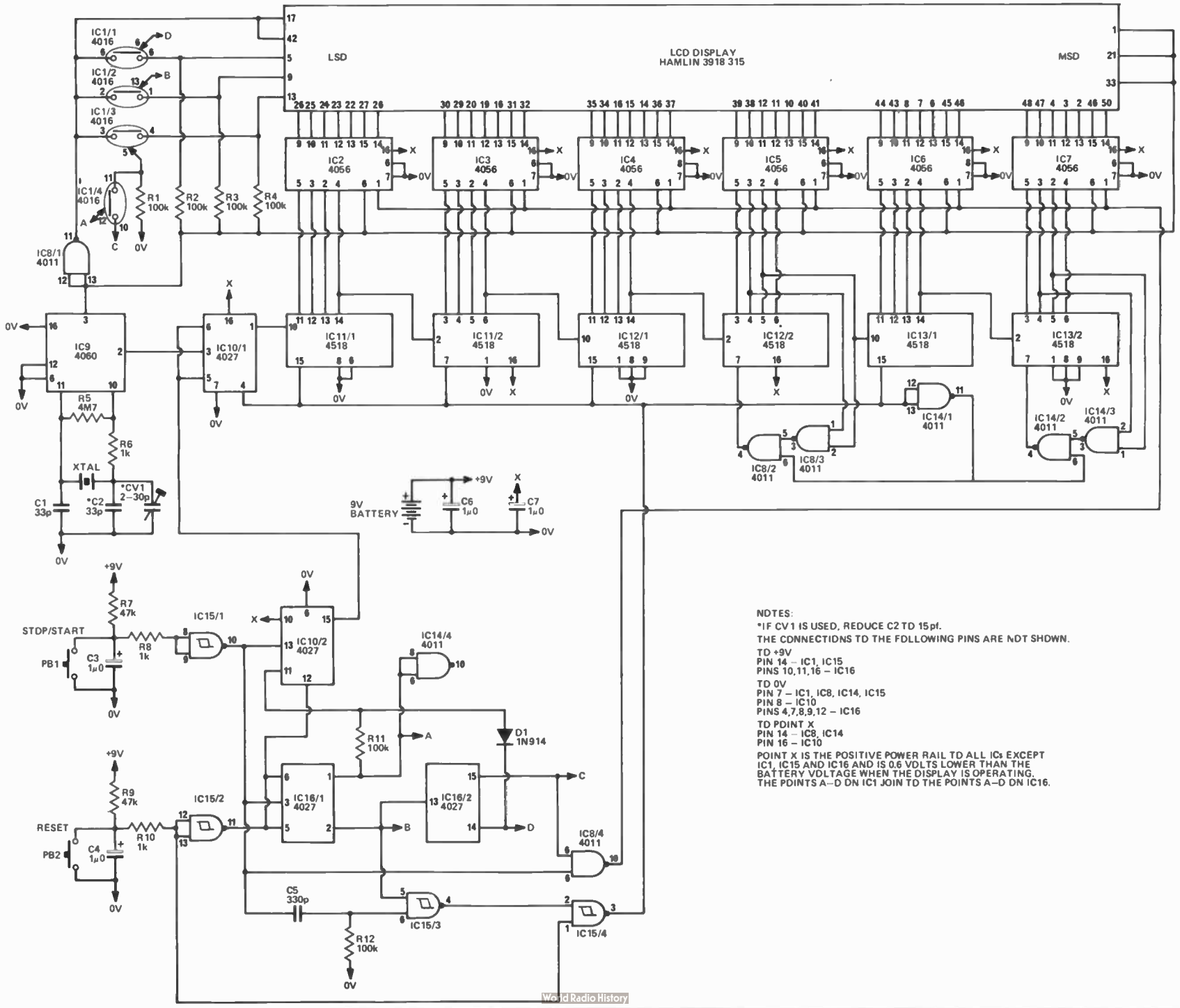

NOTES:

*IF CV1 IS USED, REDUCE C2 TO 15pf.

THE CONNECTIONS TO THE FOLLOWING PINS ARE NOT SHOWN.

TO +9V
PIN 14 – IC1, IC15
PINS 10,11,16 – IC16

TO 0V
PIN 7 – IC1, IC8, IC14, IC15
PIN 8 – IC10
PINS 4,7,8,9,12 – IC16

TO POINT X
PIN 14 – IC8, IC14
PIN 16 – IC10

POINT X IS THE POSITIVE POWER RAIL TO ALL ICs EXCEPT IC1, IC15 AND IC16 AND IS 0.6 VOLTS LOWER THAN THE BATTERY VOLTAGE WHEN THE DISPLAY IS OPERATING. THE POINTS A–D ON IC1 JOIN TO THE POINTS A–D ON IC16.

Fig. 1. The complete circuit diagram of the stopwatch.

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HOW IT WORKS – ETI 590

Let's start in the middle. IC9 is a crystal oscillator and divider, which, using a 1.6384 MHz crystal, gives 200 Hz on pin 2 and 100 Hz on pin 3. If necessary the crystal frequency can be adjusted by CV1, but normally a 33 pF capacitor for C2 will be accurate enough. The 200 Hz output is divided by 2 in IC10/1 if pins 5 and 6 of that IC are high. The resulting 100 Hz drives IC11/1 which divides by 10, IC11/2 and IC12/1 which also divide by 10, IC12/2 which, due to IC8/2 and IC8/3, divides by 6, IC13/1 (divide by 10) and finally IC13/2 (divide by 6). This is a total division by 360 000, giving an output (not used) from IC13/2 of one hour.

The BCD outputs from each of these dividers is decoded by IC2 - IC7 which are the display decoder/drivers. These ICs need the backplane frequency as an input so that the outputs will either be in phase (display off) or out of phase (on). Also included on these ICs are the latches required to hold a steady display while counting continues.

Keeping It Under Control

Two push buttons are used, one for start/stop and the other for reset. Both are debounced and buffered by schmitt triggers. If the reset button is pressed the reset input to IC10/2 (pin 12) goes high, forcing the Q output (pin 15) low. This stops IC10/1 from dividing, which stops the display. The reset button also places a low on pin 1 of IC15 causing the reset line of the counter to go high, resetting the contents to zero.

Before going any further we had better explain the mode control. This is done by IC16 which is connected as a divide by four counter. If the reset button is pressed a high will be applied to the J-K terminals of IC16/1 and if the start/stop button is now pulsed, each pulse will advance the counter by one. The A-D outputs for the four modes are given below:

	A	B	C	D
Mode 0 (off)	0	1	0	1
Mode 1 (normal)	1	0	0	1
Mode 2 (lap)	0	1	1	0
Mode 3 (total)	1	0	1	0

These modes are selected sequentially with mode 0 following mode 3. Now back to the operation of the main circuit.

In mode 1 we have a '1' on pin 11 IC10 (K input), due to the mode selector, as well as a permanent '1' on the J input. In this mode, the start/stop button will alternate the output of IC10/2 on each press, enabling and disabling IC10/1.

Also in this mode there is a low on pin 9 of IC8/4, forcing the output high. This opens the latch in the decoder ICs and the contents of the counters will be continuously displayed. Counting is therefore alternatively started and stopped by the start/stop button without resetting. If the reset button is pressed the counters are reset and IC10/2 forced into the stop condition.

In mode 2 (lap timing) we have a low on pin 11 of IC10/2, and a high on pin 9 of IC8/4. If the reset button is pressed the counters are reset to zero and IC10/2 is forced into the stop condition. Pin 10 of IC15/1 will be low (push button open) and this signal on pin 8 of IC8/4 will force pin 10 high, thus opening the latches. Zero will be displayed. Pressing the start/stop button will toggle IC10/2 into the start mode, allowing the counters to be advanced. If the button is held pressed the high on the input of IC8/4 is lost and the latches are closed. The result is that although the counters are being advanced the display will still read zero. Releasing the button will cause the display to immediately update to the correct reading and continue to follow the counting.

If the start/stop button is again pressed IC10/2 will not be affected as the J-K inputs are 1,0 and not both high. However, while the button is depressed the latches are closed and the time until the button was pressed will be displayed. Also at the instant the button is depressed a positive pulse of about 25 μs is generated by C5/R12 and as the other input of IC15/3 is high, this pulse results in a 25 μs wide negative pulse on pin 4 of that IC. This resets the counter ICs (via IC15/4) back to zero, although this cannot be seen as the latches are closed. Releasing the button will allow the display to update to the time from the last press. In this mode the result is that the time between presses of the start/stop button is displayed for as long as the button is held down.

In mode 3 the operation is identical to mode 2 with the exception that the reset pulse due to C5/R12 is disabled by a low input on pin 5 of IC15/3. The result of this is that the time displayed is the total since the first press of the start/stop button.

The mode indication is done by IC1; depending on the status of the mode counter one of IC1/1, IC1/2 and IC1/3 will be on. In mode 0 both IC1/1 and IC1/2 will be on.

Power? The astute reader may have noticed that the 9 V supply only goes to IC1, IC15 and IC16! The input protection on CMOS ICs consists of diodes to the power rails, and if any input is taken above the supply rail the protection diode will conduct; if there is enough energy and the load on the power supply is very light the power supply voltage will rise. If there is no power supply and an input is taken to +9 V the power supply will rise to about 8.4 V. Care has to be taken not to damage the protection diodes, however. Getting back to this circuit, in mode 1, the high output on point A (IC16/1) will supply current to the rest of the ICs via the protection diodes in IC14/4. In modes 2 and 3 it is supplied via IC8/4. In the off mode there is no path unless one of the push buttons is depressed. In this case it is supplied via IC10/2 or IC8/4. The current in the off state was measured as about 20 nA, mainly being leakage in C6.

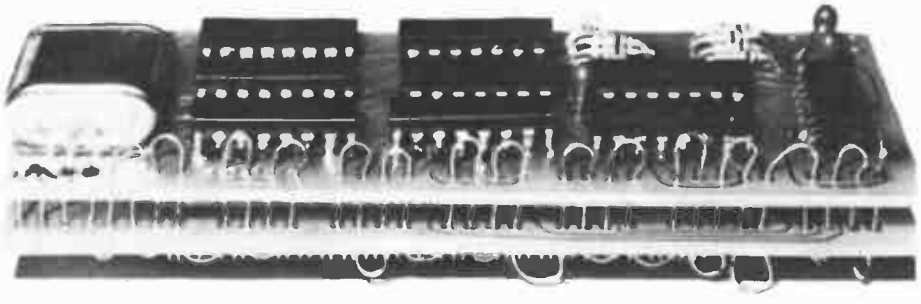

Photo showing how the two boards are wired together. After soldering the loops any excess should be cut off.

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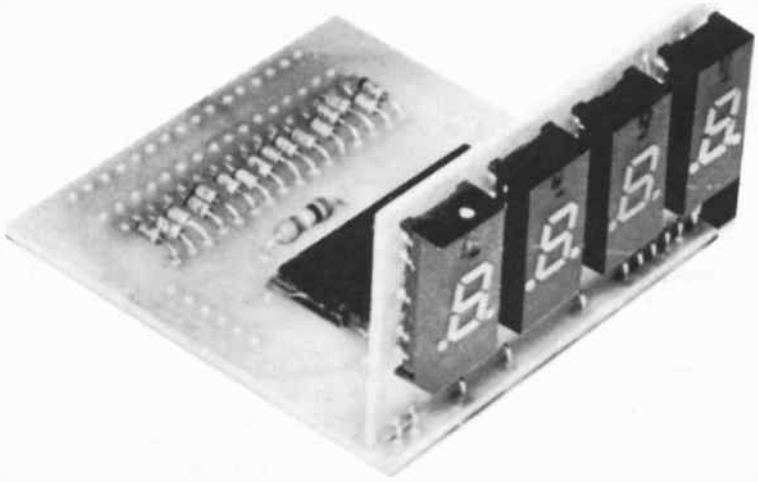
UP/DOWN PRESETTABLE COUNTER



THE THREE DIGIT display (ETI 533) we previously published has proved to be one of our most popular projects. We have used it in a number of projects and we know of several commercial companies using it in their own equipment.

Many people have asked us for a 4 digit version and we have been looking round at ICs available. We have chosen this Intersil device because we believe it offers the best versatility at the moment. Apart from being a 4-digit counter-latch-decoder driver needing no external components except the displays, it also is an up-down counter and can be preset to any number. In addition, it has a separate register which also can be set to any number and comparators which give outputs when the counter is equal to the register and when it is zero - all in one IC!

Construction

The unit is built on two small pc boards which are connected together with short links of tinned copper wire. Be careful to orientate the IC correctly as it is expensive!

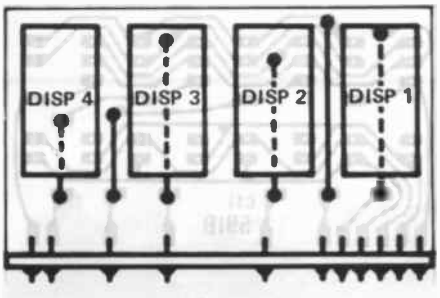
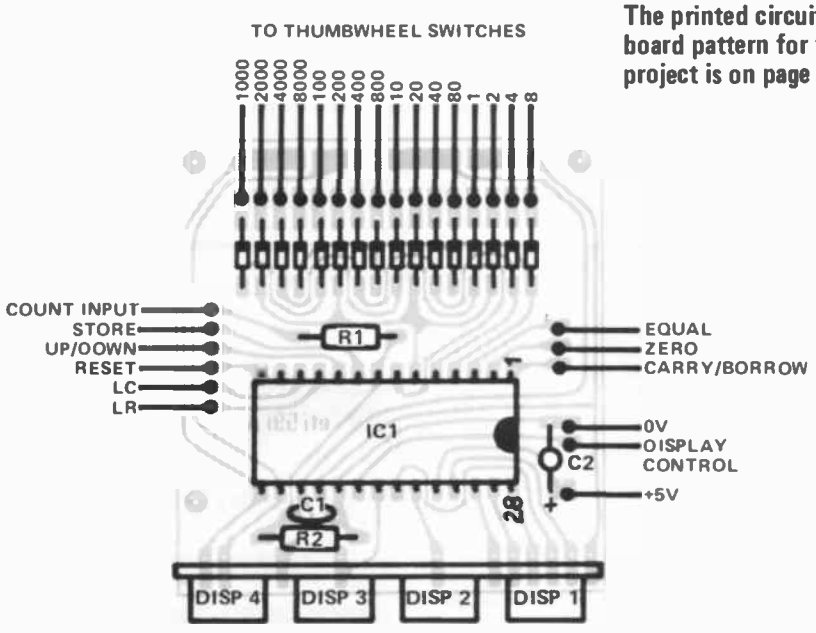


Fig. 1. The positioning of the displays and the links which must be installed before the displays.

Fig.2. The component overlay for the main board. The common connection from each of the thumbwheel switches goes to the track next to the other connections.

The preset system is designed to use a 4 digit BCD thumbwheel switch (closed = '1') but individual switches can be used if required. Input is in BCD, therefore the switches will have the weighted values 8, 4, 2 and 1. If the preset is not needed then the diodes can be left out. If a preset is needed, but always to a fixed number, links can be inserted to replace the "on" switches and the other diodes left out.

The printed circuit board pattern for this project is on page 127.



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HOW TO USE IT

This section is normally How it Works but as it is only one IC there is not much to be said!

Count Input - Pin 8
The counter is incremented or decremented on the leading edge of this input. A schmitt trigger is provided with a 500 mV hysteresis on a 2V trigger point. For high speed operation, or operation from a digital output, delete R2 and C1 and short out R1. Maximum frequency of operation is about 2 MHz.

Up-Down - Pin 10
If this pin is left open or taken to +5V the counter will be incremented by the count input. If it is taken to 0V the counter will be decremented by the count input.

Reset - Pin 14
If this pin is left open or taken to +5V the counter is free to be incremented or decremented. If it is taken to 0V the counters will be reset to zero and held there until reset is taken high again.

Store - Pin 9
If this input is left open or taken to +5V the latches are "closed" and the information which was in the counters at the time the store input went high will be remembered, decoded and displayed. The counters can be reset, incremented or decremented without affecting the display.

If it is taken to 0V the counter contents will continuously be displayed for as long as this input is at 0V. Any change in the counter contents will be shown on the display.

Load Counter - Pin 12
This is a 3 level input. If it is left open the counter works normally. If it is taken to +5V the counter is loaded with the BCD data which is set on the thumbwheel switches. If the latch is open, this number will also be displayed. If this input is taken to 0V the BCD I/O pins become high impedance. If a 3 level input is to be controlled by other logic outputs they must be tristate devices.

SPECIFICATION

Number of digits	4
Readout	LED
Maximum frequency	2MHz
Input impedance	100k
Output drive	1 TTL load
Supply voltage	4.5 – 5.5V
Supply current	
low power mode	500μA
all eights	100mA

PARTS LIST

Resistors all ½W, 5%
- R1 . . . . . 100k
- R2 . . . . . 1M

Capacitors
- C1. . . . . 33n polyester
- C2. . . . . 1μ0 35V tantalum

Semiconductors
- IC1 . . . . . ICM 7217A
- D1–D16 . . 1N914
- DISPLAYS. DL704

Miscellaneous
- PC boards ETI 591A, ETI 591B

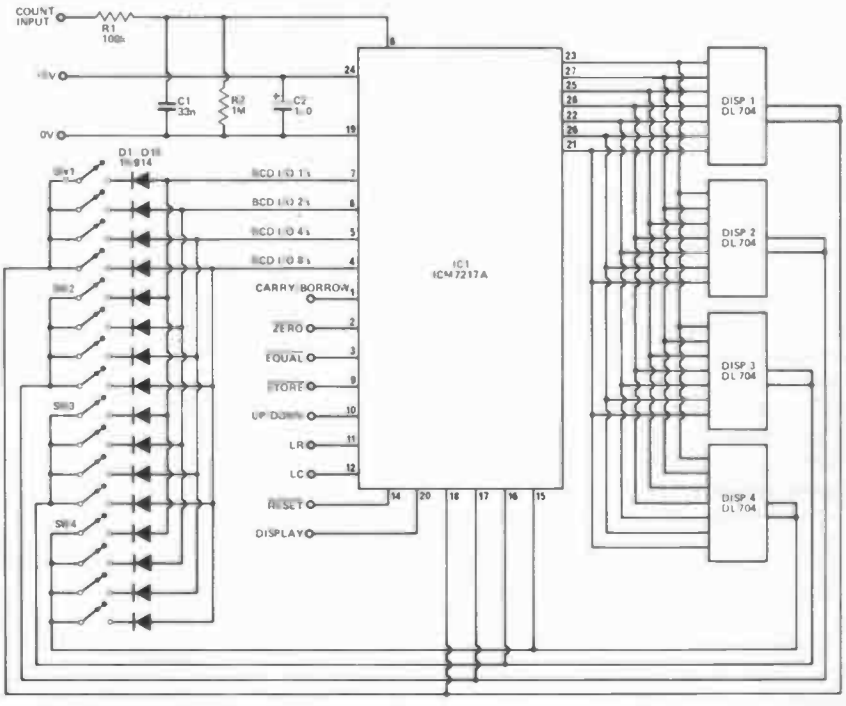

Fig. 3. The circuit diagram for the counter board.

Load Register - Pin 11
This is also a 3 level input. If it is left open the counter works normally. If it is taken to +5V the register is loaded with the BCD data. If taken to 0V the circuit goes to a low power state with the multiplexing oscillator stopped, the display off and the BCD I/O pins in a high impedance state. The operation of the counter is unaffected except that there is no display.

Display Control - Pin 20
This is also a 3 level input. If it is left open, leading edge blanking occurs. If all digits are zero then all are blanked. If it is connected to +5V the display is completely blanked irrespective of the value. If taken to 0V all digits are ON irrespective of value.

Scan - Pin 13
The internal multiplexing frequency is nominally 10 kHz giving a digit repetition rate of 2.5 kHz. With a 20 pF capacitor from this point to 0V the frequency drops to 5 kHz and with 90 pF it is about 1 kHz.

BCD I/O - Pin 4-7
This is a multiplexed data port, normally an output which can drive 1 TTL load. It becomes an input when either LC or LR is at +5V. Pin 7 is the least significant bit.

Digit Drives - Pins 15-18
These are used both to drive the LEDs and to provide data indicating which digit is being presented at the BCD I/O port. Pin 18 is the least significant digit.

Zero - Pin 2
If the value of the counter is zero this output will be at 0V.

Equal - Pin 3
If the value of the counter is equal to the value of the register this output will be at 0V.

Carry/Borrow - Pin 1
When the counter goes from 9999 to 0000 or from 0000 to 9999 a 500 ns positive pulse occurs on this output. This is connected to the count input of a second unit when an eight digit display is needed.

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Project 719

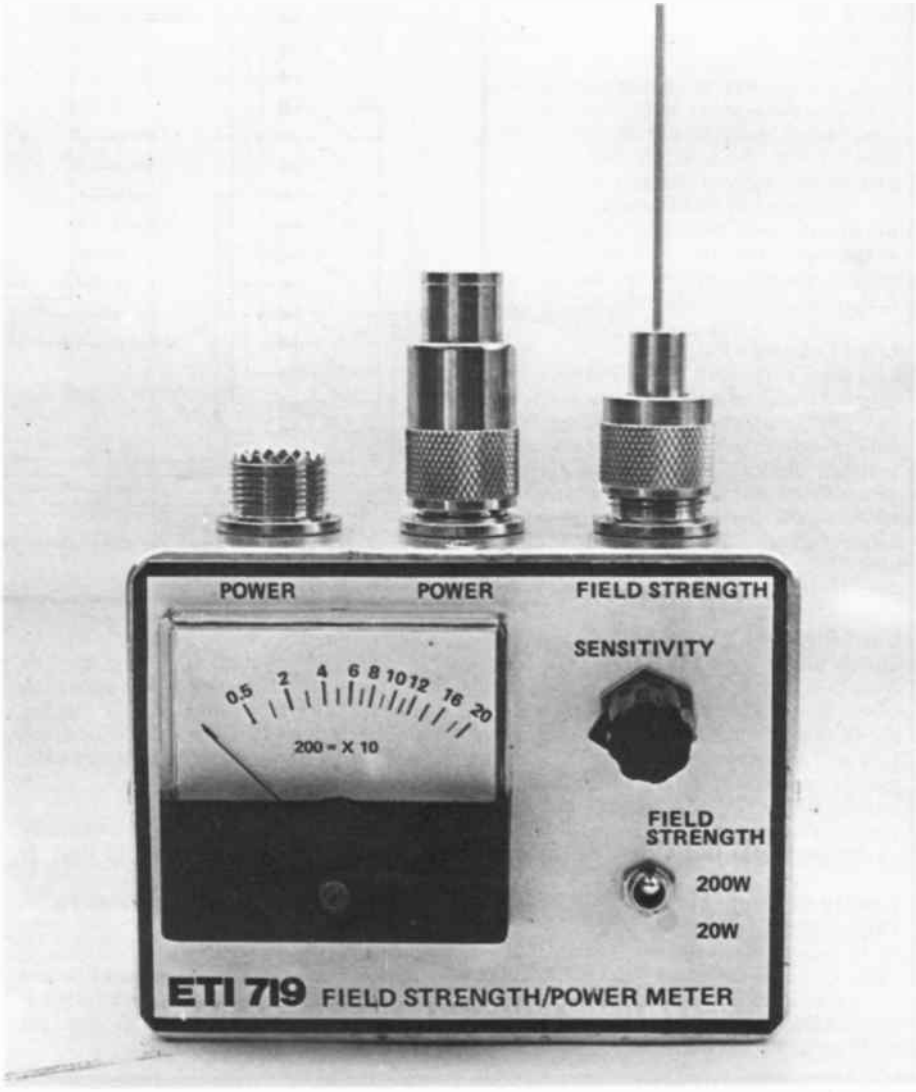
Field strength - power meter

Versatile unit indicates transmitter tune-up.

TWO PIECES OF equipment which are almost essential to the CB'er, novice, or amateur alike, are a field strength meter and a power meter. This design combines the two in a simple easy to construct circuit comparable to equipment many times its cost.

Measurement of field strength is useful for antenna tuning, especially where an antenna tuning unit is used, or for checking the radiation pattern of a directional antenna. If the meter is left in a fixed position well away from but at the same height as the antenna, and the antenna rotated, a circular plot of the antenna radiation pattern can be drawn up. When tuning an antenna the meter should be placed in a convenient position where it can be seen and the tuning adjusted for maximum reading.

The power meter is used to tune the output of a transmitter, or can be left in the transmission line as a monitor of power output. The reading on the meter will only be accurate if the antenna has low VSWR. For accurate power measurement, and for transmitter tuning, a dummy load should be connected to one of the power sockets. If only the 20 watt range is used a small CB dummy load is suitable, a larger load of course being necessary for the 200 watt range. Table 1 gives the power calibration for both ranges for a 50 μA meter or the scale can be cut from page 118.



Construction

Figure 2 shows the wiring layout for the unit. This layout should be strictly adhered to, otherwise performance may

World Radio History

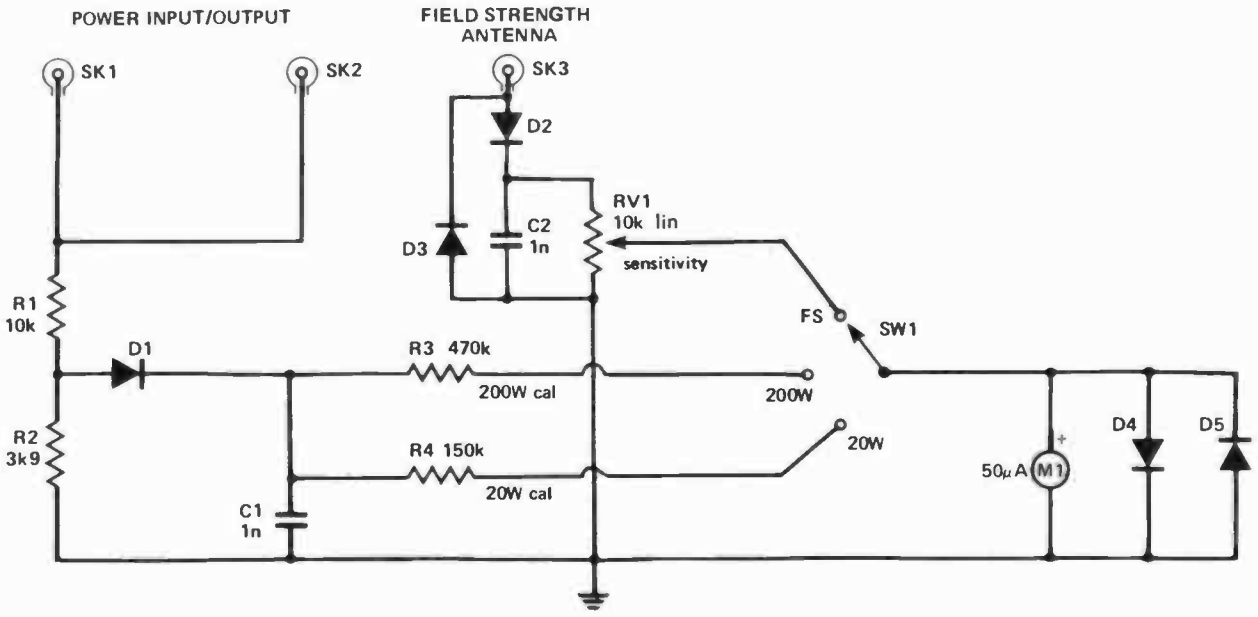


Fig. 1. Circuit of the Field Strength/Power meter.

be affected. All leads, especially the earth leads, should be kept short.

Components for the power meter are assembled on a small piece of matrix board, which is then held in place by the meter terminal screws.

We used a Horwood instrument case type 32/2/D, available from Radio Dispatch Service or Dick Smith Electronics, which measures only 75 mm x 100 mm x 50 mm deep. A C&K type 7211 toggle switch is used for the function switch, although any suitable switch which will fit into the constraints of the box will do equally as well.

A whip antenna for the field strength meter was made by soldering a length of brazing rod into a PL259 UHF plug and filling the space with Araldite. The sensitivity of the meter will increase with the length of the antenna.

Meter scale and front panel artwork are on page 129.

How It Works – ETI 719

Let's look at the field strength meter first.

Some signal is picked up by the whip antenna and is detected by D2 and C2. The capacitor, C2, charges to a voltage proportional to the field strength of the signal. A return path for the charging of C2 is provided by D3. The sensitivity control, RV1, varies the current fed from C2 to the meter, via the function switch SW1. The meter will give a reading proportional to the field strength of the signal. The diodes D4 and D5 provide meter overload protection by conducting when the voltage across the meter terminals exceeds about 0.7 volts.

Power Meter

The power meter is similar in operation to the field strength meter, but instead of taking the signal from the antenna it measures the voltage on a 50 ohm transmission line. R1 and R2 form a voltage divider to reduce the voltage to be measured and to provide isolation between the measuring circuit and the transmission line. The RF signal is then detected by D1 and C1, the voltage across the capacitor being proportional to the voltage on the transmission line. The power in the line is then proportional to the square of this voltage ($P = V^2/R$ and $R = 50\Omega$). This voltage is measured by a dual range peak reading voltmeter formed by R3, R4 and M1. The meter is calibrated for 20 watts and can also be used for the 200 watt range. The voltmeter gives an accurate reading for both carrier power (AM), and peak envelope power (PEP).

METER CALIBRATION

Power	Scale		
0.5	8	9	33.5
1	11	10	35
2	16	11	37
3	19	12	38.5
4	22	14	42
5	25	16	44.5
6	27.5	18	47.5
7	29.5	20	50
8	31.5		

World Radio History

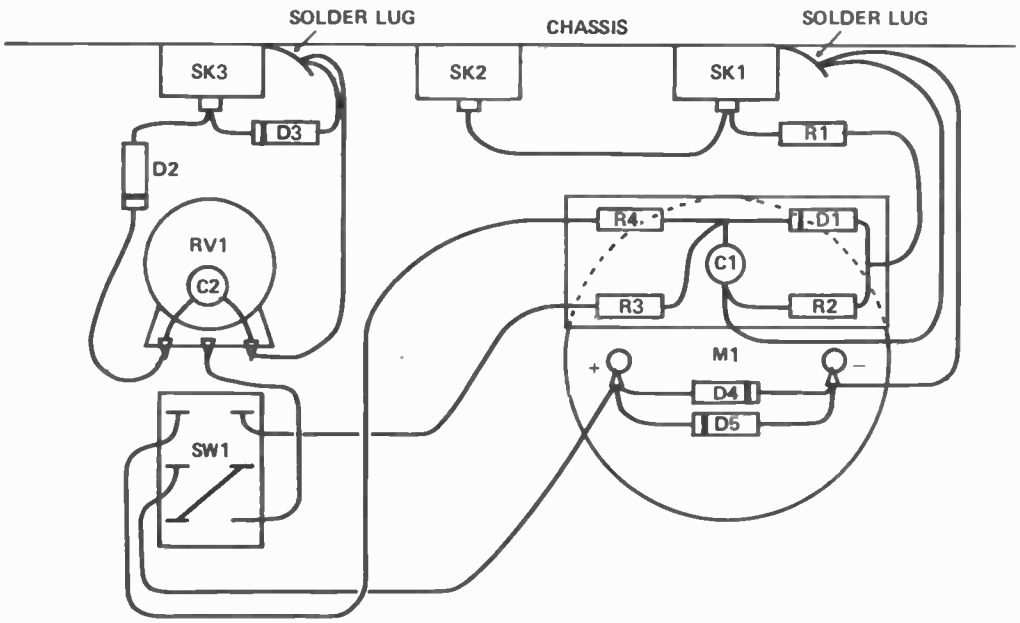
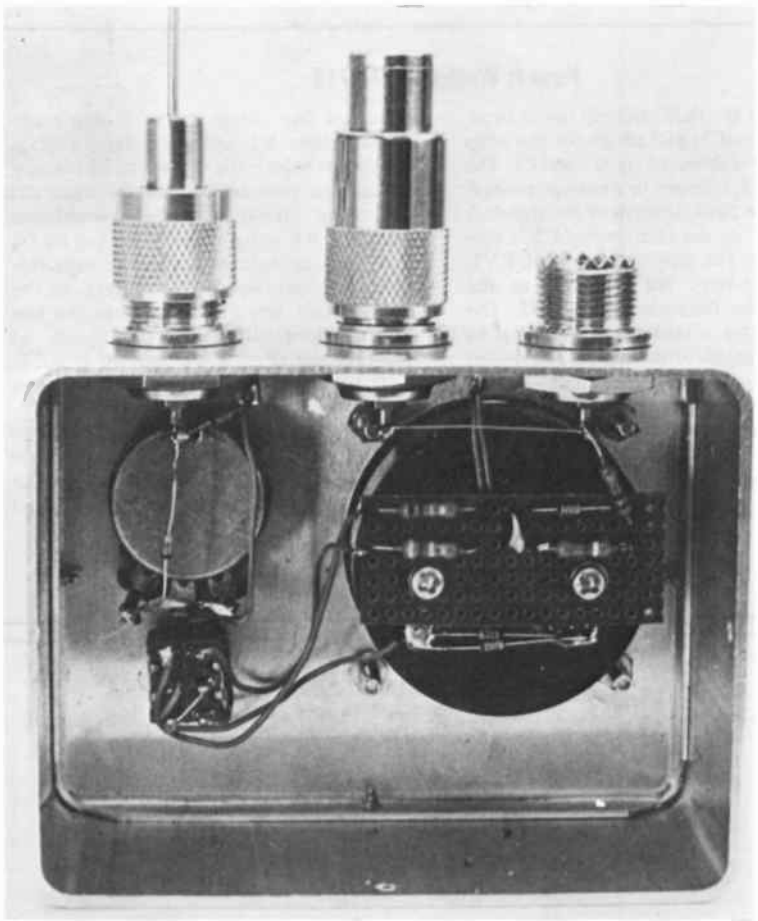


Fig. 2. Wiring layout of the unit. Matrix board is used to mount the components for the power meter.



The completed meter. All leads, especially the earth leads, should be kept as short as possible.

PARTS LIST – ETI 719

Resistors all ¼W 5% except R1
R1 . . . . . .10k 5% ½W
R2 . . . . . .3k9
R3 . . . . . .470k
R4 . . . . . .150k

Potentiometer
RV1 . . . . . .10k lin.pot.

Capacitors
C1, 2 . . . . . .1n ceramic

Diodes
D1 – D5 . . . . . .1N914

Miscellaneous
SW1. . . . . .C&K 7211 (see text)
SK1 – SK3 . . . .S0239 UHF socket
M1 . . . . . .50 μa 50 mm meter
Horwood instrument box 34/2/D (see text)

Accessories
50ohm CB load
PL259 UHF
C2. . . . . .1000u 25VW electro
SW1. . . . . .SPDT min. toggle

World Radio History

Project 136

Linear-Scale Capacitance Meter

If you want to find out what values those odd capacitors are, then here's the instrument for you.

ONE OF THE handiest instruments for an electronics hobbyist, or an electronics workshop, is a capacitance meter. Every multimeter has a resistance scale – and it gets used quite often. But there is often a requirement for measuring capacitance, and few multimeters have a capacitance range.

For example, measuring the value of a variable capacitor used to temporarily 'trim' a filter or oscillator that is to be replaced by a set of fixed capacitors. Or a bagful of 'bargain' unmarked capacitors may have been obtained or the color code or numeral code has disappeared and the value of a component needs to be determined.

Once you have a capacitance meter, you suddenly find uses for it!

This capacitance meter provides a linear scale readout of the value of unknown capacitors generally to within 5% or as good as 2% depending on the accuracy of the meter used.

Range

The meter will measure capacitance values down to 5 pF and up to 1 μF. Scale divisions on the model shown were at 2.5% intervals.

Five ranges are provided: 100 pF, 1 nF, 10 nF, 100 nF and 1 μF.

Different ranges can be provided by selecting different values for the range resistors R7 to R11. For example, five ranges from 47 pF to 0.47 μF could be included by changing R7 to 470 ohms, R8 to 4.7k etc. The meter scale would have to be hand-calibrated in this case.

Construction

The construction is quite straightforward. The majority of the small components are mounted on the printed circuit board. The range resistors are mounted on the switch lugs as illustrated in the photographs.

All the range resistors, R7 to R11, and R12 are high tolerance 1% or 2% resistors accurately measured to be within the tolerance required. If only 5% or 10% accuracy of capacitance value is required then standard 5% or 10% tolerance resistors may be used, obviating the need for selecting them, or buying the expensive high tolerance types.

SPECIFICATION – ETI 136

Capacitance ranges	100 pF, 1 nF, 10 nF, 100 nF, 1 μF.
Accuracy	5% or better (2% possible with component selection)
Calibration	by internal calibration capacitor
Power requirements	240 V AC or 2 x 9V No. 916 batteries

World Radio History

Project 136

The printed circuit board, meter, range switch, potentiometers, pilot light measurement terminals and on/off switch are all mounted on the front panel as illustrated.

The power supply is mounted on the back panel, as is the mains/battery switch. The batteries (if used) may be mounted inside the case. Overall case size is 180 mm wide by 95 mm deep by 128 mm high.

A small tagstrip is used to terminate the mains input and transformer leads and the rectifier components. Both the back panel and the front panel should be connected to the mains earth which is terminated on the tagstrip, the strip's earth tag being secured under one of the transformer mounting bolts.

The calibration capacitor is a high tolerance (2% or better) polystyrene or, better still a silver mica type. This component is mounted from the appropriate switch lug to a suitable ground lug mounted on the front panel.

The printed circuit board has PC stakes (or pins) soldered in all the positions marked on the component overlay.

Two of these (marked E and Cx on the PC artwork) are used to mount the PCB directly on the back of the "Cx" terminals, as illustrated in the photographs. This avoids increasing the circuit stray capacitance.

Little difficulty should be experienced if the component overlay is followed and the photographs are referred to during construction.

Note that alternative panel layout is possible if a standard type of panel meter is used rather than the edgewise meter shown in the photographs.

The front panel was hand-lettered with Letraset on the prototype. A Scotchcal type front panel could also be prepared if desired.

The CAL. potentiometer is a screwdriver-adjust type and was mounted with a fixing collet. Knob-twiddlers can cause havoc.

Using the Meter

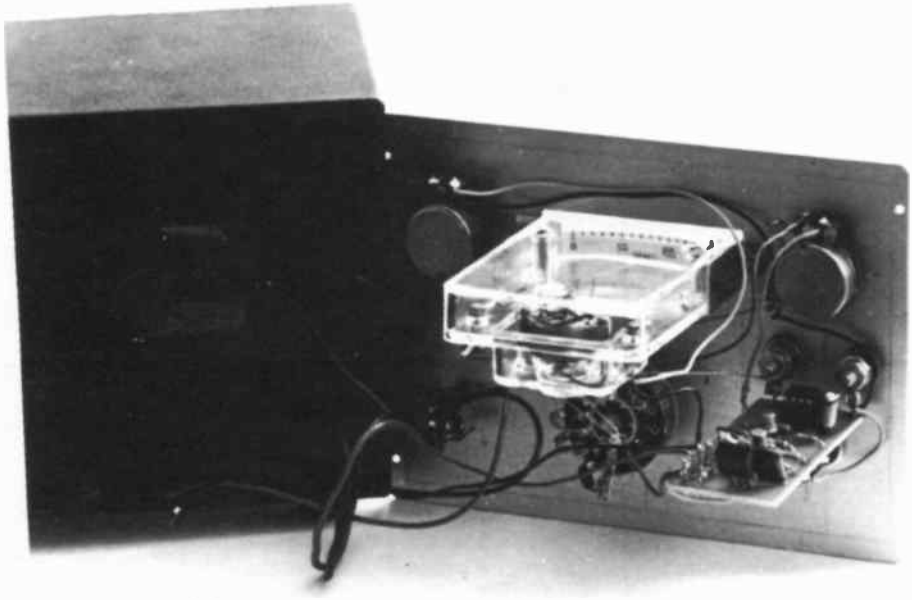
Once the instrument has been tested and confirmed to be in working order, switch the range switch to the 100 pF position and turn the SET ZERO control so that the meter reads zero with no capacitor connected to the Cx terminals. Then switch to the CAL. position and adjust the CAL. potentiometer so that the meter reads full scale.

Now you are set to measure all those 'unknown' capacitors.

Any devices used to grip capacitors being measured, and plugged into the Cx terminals, will add stray capacitance and this will need to be compensated for by readjusting the zero set control.

Continued on page 94.

Note: Suitable edge meters are often obtainable from surplus component stores. The particular meters are 0–1 mA movements calibrated 0–5 ounces. The scale is easily removed and reversed to provide a blank scale which can be hand-calibrated (use a reg. voltage supply, a good pot and a mirror scale or digital meter to set the current points). This is best done with the meter mounted on the panel. Excellent accuracy can be obtained.



PARTS LIST – ETI 136

Resistors

R1	560k, ¼W
R2	470 ohm. ¼W
R3, 6, 13	1k5. ¼W
R4	120 ohm
R5	10k, ¼W
R7	1k, ½W. 2%
R8	10k, " " either use 2% tol.
R9	100k " " resistors or selected 5% or 10% tol. see text.
R10, 12	1M " "
R11	10M " "
RV1	10k/A panel mounted, screwdriver adjusted
RV2	500 ohm/A pot.

Capacitors

C1	3n3, Philips polystyrene or silver mica
C2	10nF greencap or ceramic
C3	1nF Philips polystyrene (selected, 2%) or silver mica, 2%
C4	100nF greencap
C5	100nF greencap
C6	640 uF, 25V electrolytic

Semiconductors

D1	EM401 or similar
S1	DPST or DPDT, 250 V AC rated min. toggle switch
S2	SPDT or ½-DPDT min, toggle switch
S3	single pole, six-position OAK switch
Q1	2N2646
Q2	BC107 or BC108, BC109 or equivalent
IC1	LM555 or NE555 timer IC.
IC2	78L12 (preferred) or 7812 or LM340-T12

Miscellaneous

T1	PF2851 or M2851, 12.6 V C.T. @ 150 mA
Pilot	12 V, 20 mA bayonet lamp and holder.
Case	Instrument case, Australian Transistor Co. model 754 or similar
M1	0-1 mA meter, see text
Sundries	pk screws, wire, batteries, nuts, bolts, tagstrip, etc.

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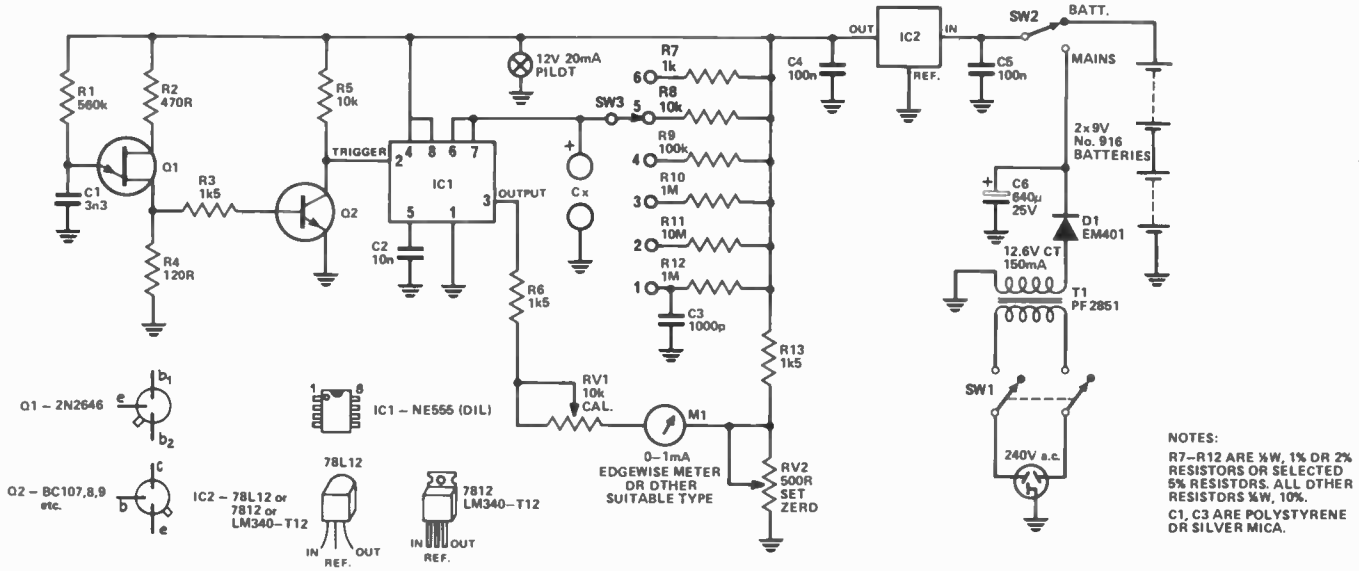
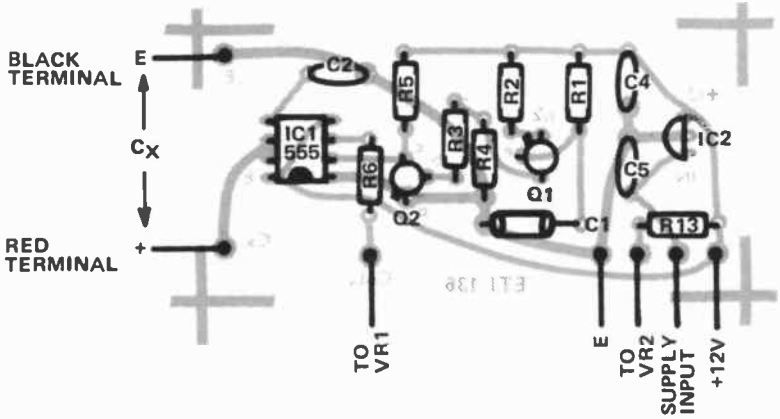


NOTES:

R7–R12 ARE ½W, 1% OR 2% RESISTORS OR SELECTED 5% RESISTORS. ALL OTHER RESISTORS ½W, 10%.

C1, C3 ARE POLYSTYRENE OR SILVER MICA.



● INSERT P.C. STAKE IN HOLES MARKED THUS.

R7-R12 and C3 are mounted on the rear of the range switch. R7 to R12 and the pilot lamp connect to the point marked '+12V' on the overlay. The common connection to switch SW3 should be taken from the point marked 'red terminal' on the overlay.

The printed circuit board pattern for this project is reproduced on page 128.

HOW IT WORKS – ETI 136

A unijunction transistor, Q1, is connected as a relaxation oscillator with a frequency determined by R1-C1. The frequency of oscillation in this instance is about 1 kHz.

Pulses of about 1 µs duration are produced across R4 each time the UJT "fires". The resistance between b2 and b1 of the UJT reduces to a low value each time the emitter conducts. Much of the charge stored in C1 is "dumped" across R4 for the short duration that the e-b1 junction of Q1 conducts.

The narrow pulses across R4 drive the base of Q2 via R3, which serves as a base-current limiting resistor. The pulses cause Q2 to conduct for the same duration, that is, about 1 µs, and negative-going pulses from the collector of Q2 drive the "TRIGGER" input of the 555 timer, IC1. This is connected to operate as a monostable in this circuit.

When IC1 receives a trigger pulse at pin 2, the flip-flop is set, releasing the short circuit across Cx and driving the output, pin 3, high. The voltage across the capacitor then increases exponentially for a period that depends on the value of the unknown capacitance Cx. The period is determined according to the formula:

$$t = 1.1\ RrCx$$

At the end of the period, the comparator resets the flip-flop which in turn discharges the unknown capacitor, Cx, and drives the output to its low state.

This cycle is repeated each time a negative-going trigger pulse appears at pin 2 of IC1.

Thus as the range resistor value (Rr) is fixed, the ON/OFF ratio of the output voltage will be determined by the value of Cx. The ON/OFF ratio is independent of the relaxation oscillator frequency and trigger pulse duration.

The current measured through the 'load' resistor on the output (R6) of IC1 will thus be directly proportional to the value of the unknown capacitor Cx.

The meter, M1, measures the current through R6, the meter inertia 'averaging' the current.

As the voltage at the output pin swings between about 2/3 Vcc and less than 1/3 Vcc in its 'high' and 'low' states respectively the DC offset is compensated for by returning the 'load' current through an offset voltage developed across VR2 via R13 from the supply rail.

Zero-setting is accomplished by making VR2 variable. A calibration control is provided by making a portion of the 'load' resistance variable – VR1 here.

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However, this will only have to be done on the 100 pF and 1000 pF ranges as the added capacitance will be negligible on the higher ranges.

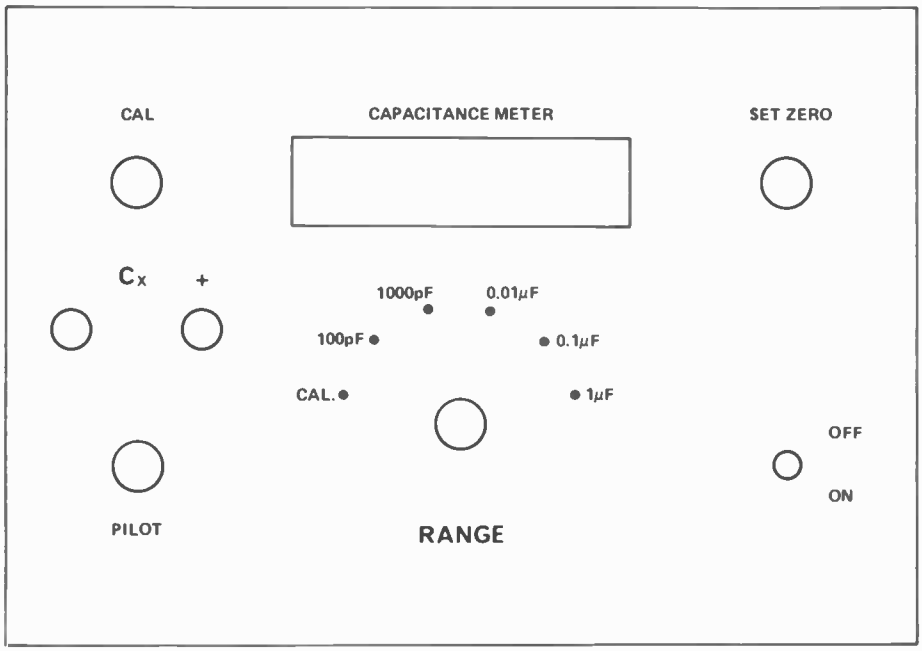
Meters

An edgewise-mounted panel meter was used in the prototype for several reasons. Firstly, we had one! Secondly, a scale nearly 50 cm long allowed us to calibrate the meter at very close intervals – 2.5% here, and still give accurate readout. Thirdly, the edge meter used little panel space, giving it a clean, uncluttered appearance.

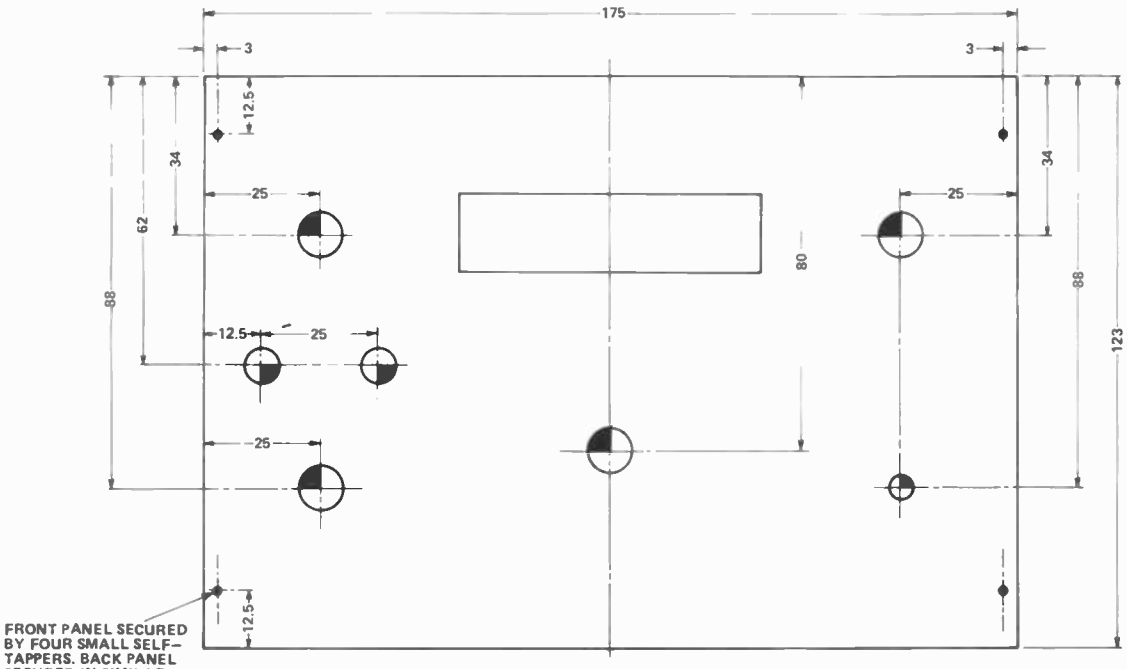
A 0–1 mA meter was used as it has a convenient scale. If you use a range with full-scale values of 47 pF to 0.47 μF a 500 μA FSD meter will have to be used.

The zero-set potentiometer, VR2, provides a small voltage offset as the output, pin 3, or IC1 does not go to zero volts and it also compensates for the effect of the small stray capacitance in the construction.

A calibration position is provided on the range switch for the sake of convenience. The original model did not have this refinement but we soon added it when we found out how useful it was! it also helps to maintain accuracy as a 'standard' capacitor does not have to be kept external to the instrument for this purpose – we kept losing ours until we put it in the circuit!



PANEL LETTERING



FRONT PANEL SECURED BY FOUR SMALL SELF-TAPPERS. BACK PANEL SECURED IN SIMILAR MANNER.

NOTES:

- 4 HOLES, 10mm DIA.
- 1 HOLE, 6mm DIA.
- 2 HOLES, 8mm DIA.
- 4 HOLES, 2mm DIA.

ALL DIMENSIONS ARE IN MILLIMETERS.

PROTOTYPE PANEL LAYOUT

World Radio History

CROSSHATCH GENERATOR

New oscillator scheme allows simplified set-up procedure.

THE COLOUR television picture is created in the receiver picture tube by three separate electron guns - one each for red, green and blue. As these guns cannot be in the same physical position they need to be converged into one spot on the screen.

The process of converging at the centre of the screen is called static convergence and is performed by magnets on the yoke assembly.

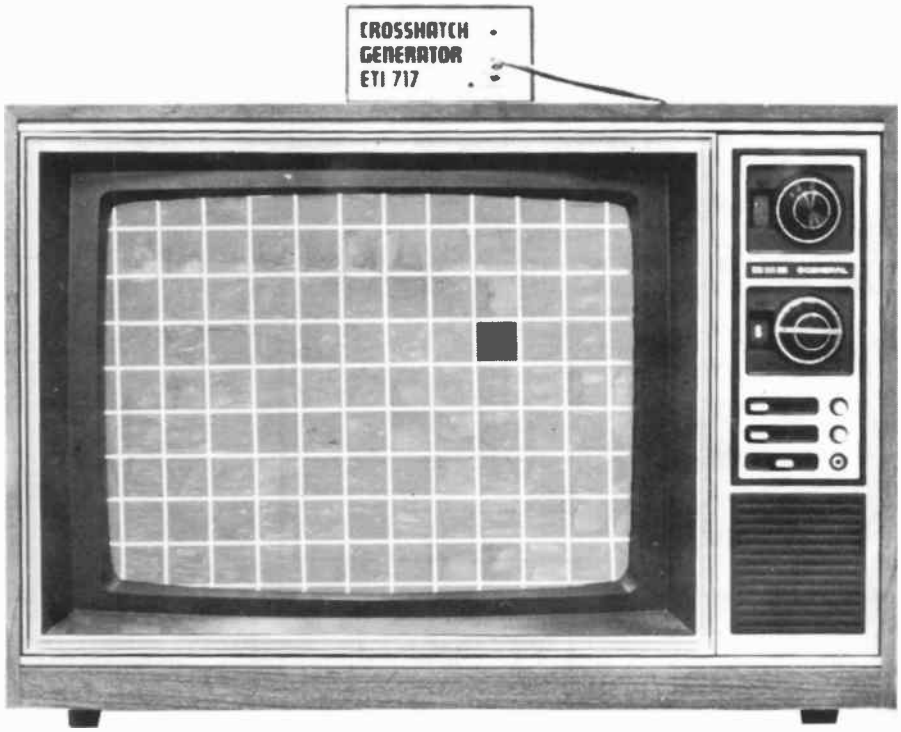
However, the screen of the picture tube is not everywhere coincident with the deflection plane and this causes errors when the beam is deflected away from centre. These deflection errors are corrected electronically by 12 or more controls and the process is known as dynamic convergence.

An important part of the process is the use of a crosshatch generator to provide horizontal and vertical lines on the screen. Using the generator, the convergence errors are immediately apparent and the controls on the set are usually labelled with the effect each has on a crosshatch pattern.

In addition to setting up convergence the generator pattern may also be used to set up horizontal and vertical linearity and to orientate the deflection yoke coils on both black and white and colour sets.

Most of the inexpensive pattern generators, which are currently available, produce a video waveform, which must be injected into the correct place in the TV, and require a synchronizing signal from the TV set. Such generators are thus fiddly things to use.

Text continued on page 98.



The new ETI 717 crosshatch generator replaces the earlier ETI 704 and is considerably easier to set up.

SPECIFICATION – ETI 717

Line spacing	
Horizontal	every 16 lines
Vertical	every 4 μs
Number of Lines normally visable	
Horizontal	9
Vertical	12
Output impedance	75 ohm
Power consumption	16 mA @ 9 V
Battery life (Type 216)	10–12 hours

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CROSSHATCH GENERATOR

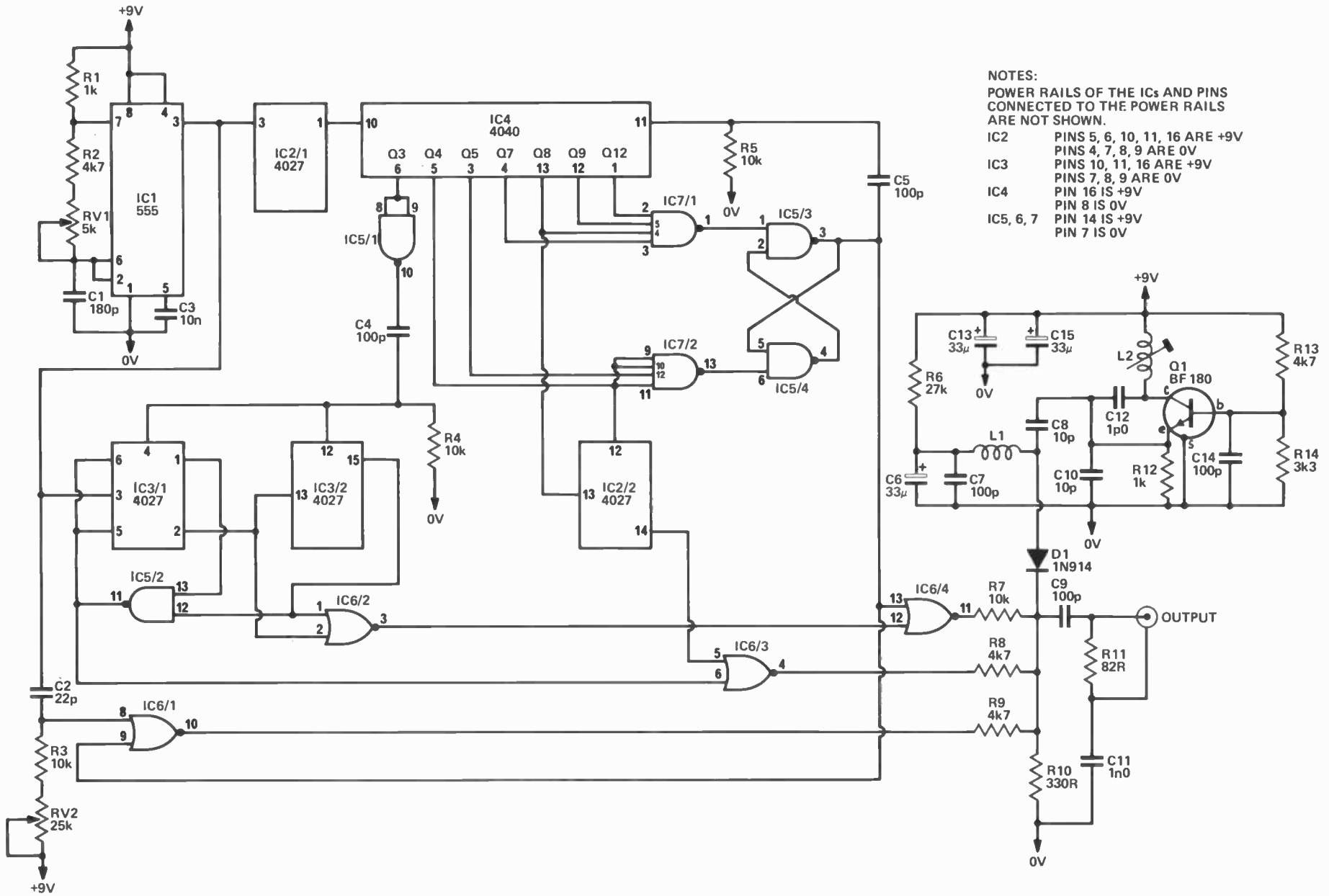

Fig. 1. The circuit diagram of the crosshatch generator.

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HOW IT WORKS – ETI 717

A TV picture is made up of a series of horizontal lines equally spaced down the screen with the information transmitted in a serial form along with the necessary synchronization pulses. In Australia there are 625 lines in each complete picture but these are transmitted as two "frames" each of 312½ lines with the second frame interlaced between the first giving a total of 625 lines. This is to reduce flicker of the picture which would otherwise occur.

To simplify our circuit and prevent a double horizontal line we have used 624 lines which eliminates the interlacing. The TV set automatically accepts this change.

To synchronize the TV set we need a 192μs wide pulse every frame (20ms) and a 4μs wide pulse every line (64μs). All pulses, including the information, are derived from a single 249.6 kHz oscillator IC1. This is divided by 2 in IC2/1 and then by 2496 by IC4 giving an output of 50 Hz. This IC is a 12 stage ripple counter which, while normally dividing by 4096, can be forced to divide by 2496 by decoding (IC7) the outputs from the 7th, 8th, 9th and 12th stages and resetting IC4 back to zero. The output of IC7 toggles the RS flip flop IC5/3, IC5/4 which resets IC4 via C5. This flip flop is reset by the decoded output from the 4th and 5th stages of IC4. This occurs 192μs later; thus the output from IC5/3 is the frame sync. pulse.

To generate the line sync pulse the output from the 3rd stage of IC4 (15,600 Hz) is used to reset both halves of the dual JK flip flop IC3. This IC is then toggled by the 249.6 kHz clock until, after three pulses, both "Q" outputs are "1" when IC5/2 detects this and disables IC3/1. IC6/2 decodes the second of these clock periods and this becomes the line sync pulse. These pulses are combined in IC6/4 to give a combined sync pulse.

The 249.6 kHz is differentiated by C2/R3 and after being squared up by IC6/1 is used to generate 16 white spots on each line which results in vertical lines. These pulses are deleted during the frame sync period to prevent interference to synchronization. Due to variations in the CMOS a trim potentiometer is provided to give equal width to the vertical and horizontal lines.

The horizontal line is generated by IC2/2 (JK flip flop) and this IC is toggled by the 8th output (487.5 Hz) of IC4 and is reset by the output of the 4th stage (64μs later). This gives a single white line every 16 lines. To prevent this line interfering with the line sync pulse the output of IC2/2 is combined with that of IC5/2 which is high for a period 4μs before the line sync pulse to 4μs after the pulse. This gives a short black region on both ends of the line (normally off the screen). The outputs of IC6/1, IC6/2 and IC6/3 are combined by R7-R10 to give a composite video signal. Note that the video information gives positive pulses while the syncronization pulses are negative.

The VHF oscillator, Q1, is mixed with this signal and the resulting modulated signal can be tuned in by the TV set. Adjustment of the frequency by the tuning slug allows operation on any desired channel from 7 to 10.

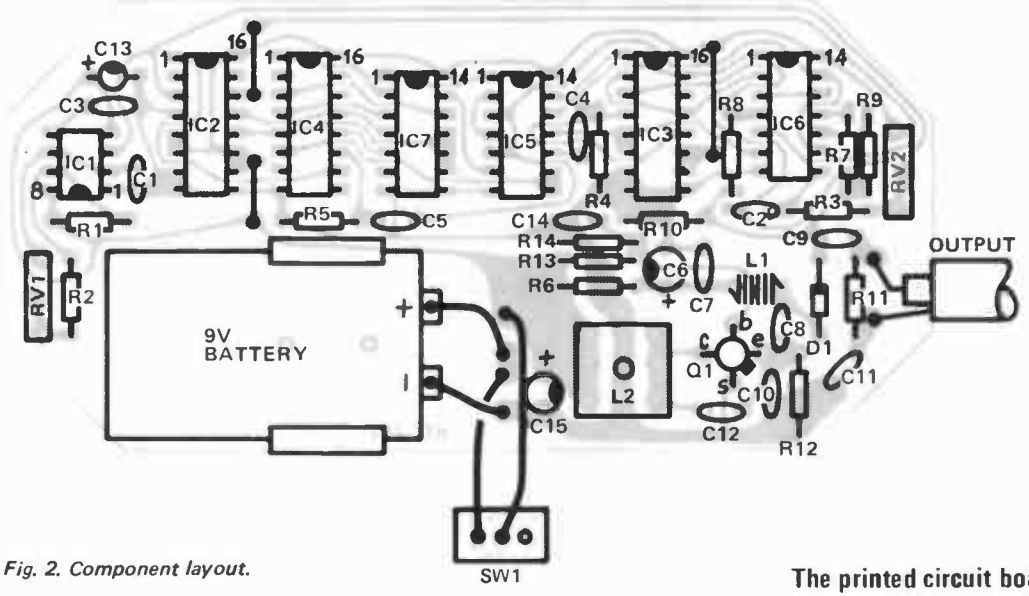

Fig. 2. Component layout.

The printed circuit board artwork for this project is on page 127.

PARTS LIST ETI – 717

Resistors all ¼W, 5%
- R1 . . . . . 1k
- R2 . . . . . 4k7
- R3–R5. . . . 10k
- R6 . . . . . 27k
- R7 . . . . . 10k
- R8, 9 . . . . . 4k7
- R10. . . . . 330R
- R11. . . . . 82R
- R12. . . . . 1k
- R13. . . . . 4k7
- R14. . . . . 3k3

Potentiometers
- RV1 . . . . . 5k trim
- RV2 . . . . . 25k trim

Capacitors
- C1. . . . . 180p ceramic
- C2. . . . . 22p ceramic
- C3. . . . . 10n polyester
- C4, 5 . . . . . 100p ceramic
- C6. . . . . 33μ 16V tantalum
- C7. . . . . 100p ceramic
- C8. . . . . 10p ceramic
- C9. . . . . 100p ceramic
- C10 . . . . . 10p ceramic
- C11 . . . . . 1n0 polyester
- C12 . . . . . 1p0 ceramic
- C13 . . . . . 33μ 16V tantalum
- C14 . . . . . 100p ceramic
- C15 . . . . . 33μ 16V tantalum

Inductors
- L1. . . . . see table 1
- L2. . . . . see table 1

Semiconductors
- IC1 . . . . . NE555
- IC2, 3. . . . . 4027B (CMOS)
- IC4 . . . . . 4040B (CMOS)
- IC5 . . . . . 4011B (CMOS)
- IC6 . . . . . 4001B (CMOS)
- IC7 . . . . . 4012B (CMOS)

Note: all CMOS should be 'B' series
- Q1 . . . . . BF180
- D1 . . . . . 1N914

Miscellaneous
- PC board ETI 717
- Zippy box
- Output socket
- Single pole toggle switch
- 9V battery

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The ETI 717 generator produces a combined horizontal and vertical sync waveform and this, together with the crosshatch video, is modulated onto a carrier frequency operating in VHF channel 8 (189.25/194.75 MHz). Thus to use the generator one simply attaches it to the antenna terminals and selects channel 8.

Table 1
Coil Winding Data

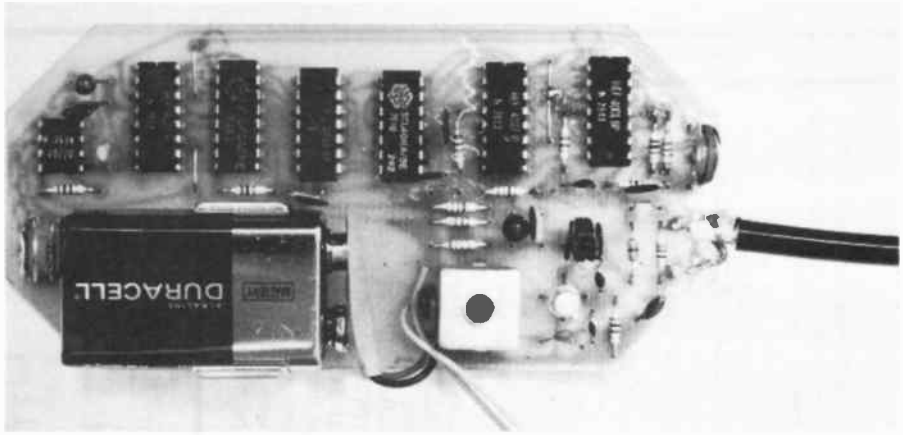
L1 6 turns 0.5 mm enamelled wire close wound, 5 mm dia, air core.

L2 4 turns 0.5 mm enamelled wire close wound onto a miniature Neosid former with VHF slug, 6 pin base and aluminium can.
Terminate leads on opposite sides of the base. Use teflon locking strip on core.

Construction

Assemble the pc board according to the overlay starting with the links, resistors and diodes. The 555 IC, the transistor, capacitors and coils next with the CMOS IC's last. Solder the power supply pins of the CMOS (7 and 14 or 8 and 16) first. This allows the internal protection diodes to protect the inputs of these ICs.

We mounted the unit into a zippy box as it is cheap and available. This does however allow the oscillator to drift due to the presence of hands, etc., as it does not provide good shielding. If the crosshatch generator is going to be used continuously a die cast box is recommended. A teflon or rubber locking strip is necessary on the adjustable coil L2 as slight movement of the slug will put it off frequency.



Alignment

This is easiest if a frequency counter or oscilloscope is available. Monitor the output on pin 1 of IC4 and adjust RV1 to give 50 Hz.

Connect the unit to the TV set and select channel 8 (or an unused channel from 7 to 10). Switch on and adjust L2 to give a stable picture. RV2 should be adjusted to give vertical lines of about the same width as the horizontal.

If an oscilloscope or counter is not available adjust L2 first to tune channel 8 as best you can and then RV1 to syncronize the picture. Now fine adjust both of these controls to give the best result.

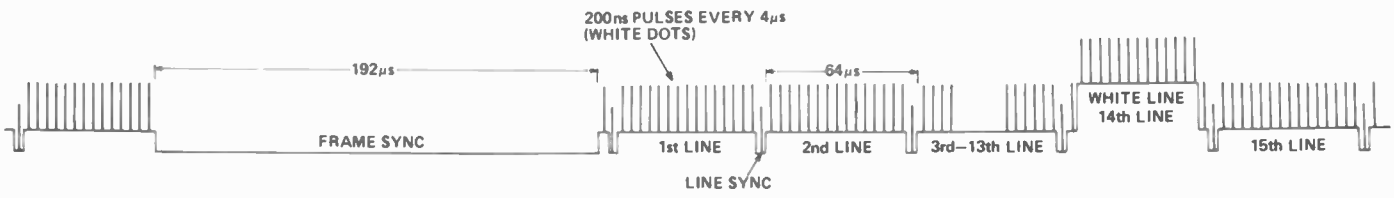


Fig. 3. Diagram showing part of the video waveform across R10. Due to the time scale involved (200ns wide pulses and 20ms between frame sync pulses) it is not possible to show the entire waveform. The first white line is the 14th and is then every 16th line.

World Radio History

Project 139

SWR/POWER METER

New design provides wide sensitivity range and wide bandwidth.
By Roger Harrison VK2ZTB and Phil Wait VK2ZZQ

THIS REFLECTOMETER DESIGN, apart from being simple, elegant and easy to construct, covers three decades – from 100 kHz to 100 MHz, and can be constructed for RF powers as low as 500 mW or up to 500 watts.

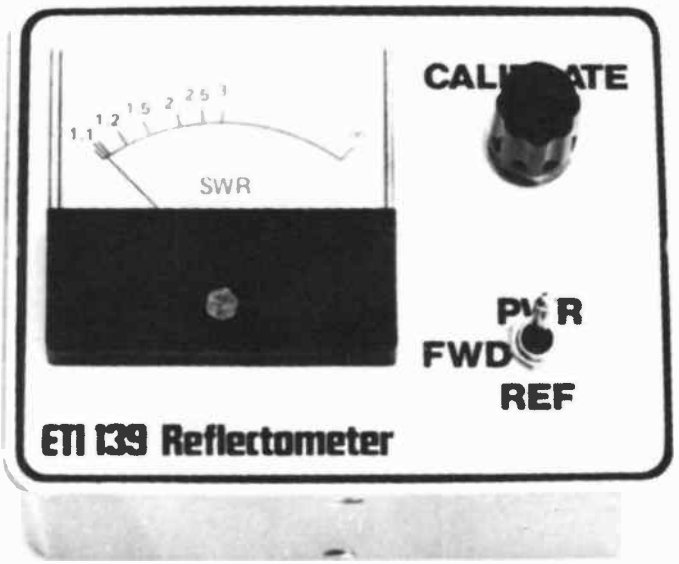
The problem with most designs for reflectometers, or "Swar" meters as they tend to be called colloquially these days, is that they generally only cover about one decade in frequency range – usually 3 to 30 MHz or, if further, have discontinuities and drastic sensitivity variations at the extreme ends of their frequency range.

Sensitivity is a problem with the commercially available instruments also. Those with the best sensitivity – 5W full scale usually – are made for the CB market, and while they will work over most of the HF spectrum (some extending beyond that), sensitivity is insufficient if you are working with low power solid state RF circuitry or doing a deal of antenna experimentation.

Performing antenna measurements at powers of 5W or more is discourteous to say the least, especially where sustained or many consecutive measurements need to be made.

The reflectometer/RF power meter described meets the requirements of most people involved in RF measurements requiring such an instrument and where a disparate variety of facilities are required.

This project will be extremely useful to radio amateurs, CBers, servicemen involved in communications, in laboratories etc.



CONSTRUCTION

Construction is very straightforward. The printed circuit design given is recommended, otherwise variations in layout may affect performance.

All the components are mounted on the *copper side* of the pc board, which is subsequently assembled onto the coax sockets and mounting bolts.

Commence by winding the toroid current transformer secondary turns. Refer to the circuit diagram. Cut a 45 mm length of RG58, stripping back the braid and insulation as illustrated in the component overlay and photographs. This is not all that critical, but maintain as much braid as you can to reduce problems with errors creeping in at the top end of the frequency range due to discontinuities here.

Slip the toroid over the short length of coax and mount this assembly on the pc board. Position the toroid centrally and fix it in place with a small amount of pliable plastic cement compound such as "Silastic".

Mount all the other components next. Pay particular attention to the orientation of the diodes D1,D2,D3.

The trimmer capacitor, C2 is shown

World Radio History

as a mica compression type. Any suitable trimmer – such as the Philips film trimmers – can be used, however, the mica compression trimmer provides a certain amount of 'vernier' adjustment.

The pc board and major components are assembled into a suitable metal box. We used a Horwood type 34/2/D which measures 100 mm by 75 mm by 50 mm. This provides for a compact finished instrument without a crowded layout.

The completed pc board is mounted in the following way:

Once the coax sockets are mounted, and the two mounting bolts are in position, a coax plug (with cable) should be plugged into each of the sockets in order to locate the centre-conductor pins of each socket.

The pc board is then placed into position and the input/output pads soldered to the coax socket pins. make sure that a good fillet of solder secures the pin to the pc board pad.

Two nuts on the mounting bolts, one under the pc board, one on top of the pc board, then secure the board mechanically as well as providing a ground connection. Refer to the pictures and component overlay.

Connections to the meter, pot, and switch – located on the front panel, can then be made with short lengths of hookup wire.

CALIBRATION

A suitable RF source, a dummy load and an RF voltmeter or a known-accurate RF power meter are required for test and calibration of the instrument.

Suitable low power dummy loads, marketed for CBers, are readily available or any of the standard amateur texts (ARRL, RSGB handbooks etc) provide excellent construction details of dummy loads to dissipate a variety of powers. The same texts describe suitable RF voltmeter probes that may be used in conjunction with a multimeter.

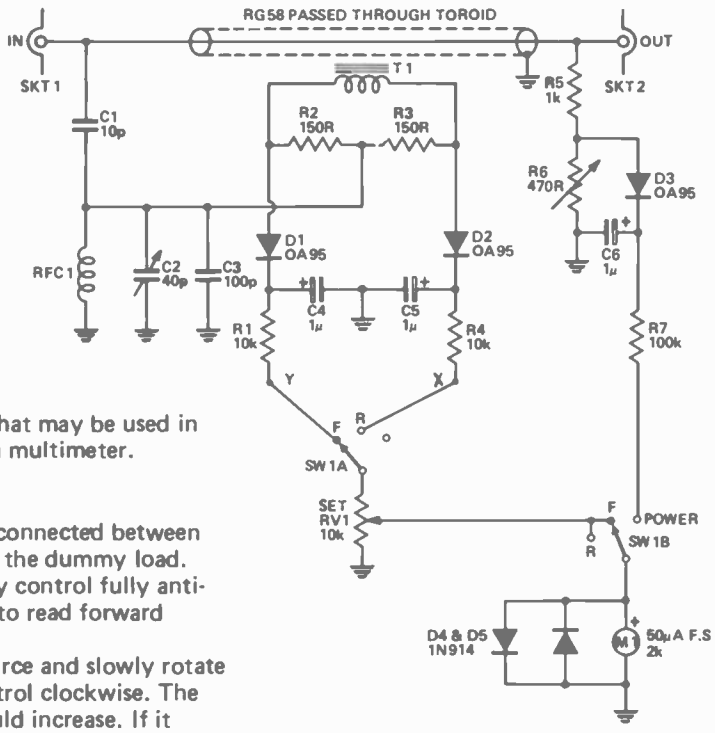


Fig. 1. Circuit diagram of the SWR/Power meter. Note the unusual switch configuration. A special C & K toggle switch was used as it provides the simplest operation. Otherwise, a double-pole, triple-throw switch is necessary.

SWR Scale

The instrument is connected between the RF source and the dummy load. Turn the sensitivity control fully anti-clockwise. Switch to read forward power.

Key the RF source and slowly rotate the sensitivity control clockwise. The meter reading should increase. If it doesn't, check wiring. If it goes in reverse, you've got D1 back to front!

If all is well, advance the sensitivity control until the meter reads full scale. Switch to read reverse power. Adjust the trimmer C2 to obtain a minimum meter reading. It should go to zero; increase the sensitivity when a very low reading is reached to ensure that C2 is adjusted correctly.

This completes the adjustment of the Reflectometer section. The scale calibration can be obtained from Table1.

The scale on the meter may be hand-lettered using Letraset or other 'rub-on' lettering. The original lettering may be painted over and the new SWR scale inserted beneath the original scale. Kit suppliers may make a whole new scale available.

Power

The circuit (Figure 1) shows a divider network, consisting of R5 and R6, tapped across the RF on the coax line.

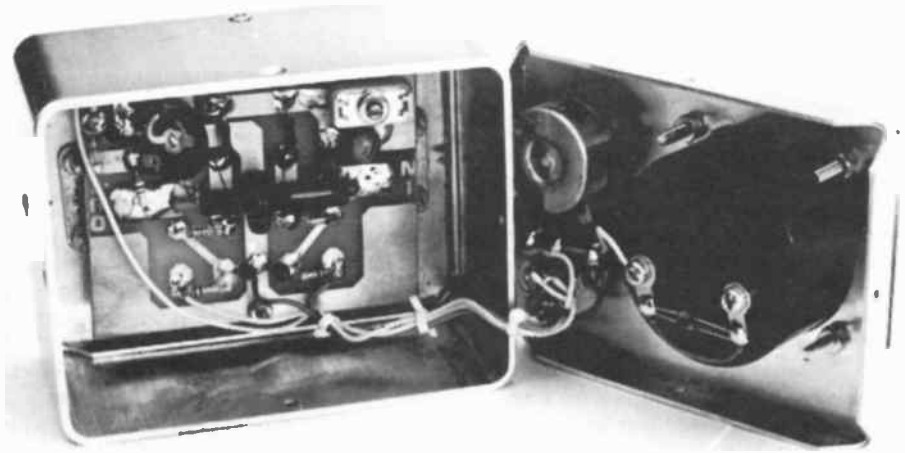
The lower divider resistance R6 is shown as a variable element. A miniature deposited carbon track trimpot was used in the prototype. The low value types seem to perform quite well over a wide frequency range and one was used here for convenience. It was set so that the full-scale reading of M1 corresponded to a particular peak power dissipated by the dummy load (as measured with an RF voltmeter or known-accurate RF power meter).

Fixed resistors may be substituted for a trimpot, necessitating only a check of the accuracy of the full scale peak power reading. Values for particular full-scale power readings are given in Table 2.

The power scale should be calibrated to suit the individual instrument. It will be non-linear, particularly at the bottom end.

Performance

The inherent impedance of the prototype instrument was measured using a TEK 5 W dummy load and a Hewlett-Packard vector impedance voltmeter. The results are illustrated in Figure 4.



World Radio History

TABLE 1

SWR	Scale reading
3:1	0.5 full scale
2.5:1	0.42 full scale
2:1	0.34 full scale
1.5:1	0.2 full scale
1.2:1	0.1 full scale
1.1:1	0.05 full scale

TABLE 2

Peak Power, full scale	R2 value
500 W	6R8
200 W	2 x 33R in parallel
100 W	33R
50 W	68R
20 W	2 x 330R in parallel
10 W	330R
5 W	680R
3 W	1k + 100R in series *

*linearity suffers

The printed circuit board layout for this project is reproduced on page 130.

PARTS LIST – ETI 139

Resistors all ¼W, 5%
R1 . . . . . 10k
R2,R3 . . . 150R
R4 . . . . . 10k
R5 . . . . . 1k
R6 . . . . . 470R trimpot or fixed –see text
R7 . . . . . 100k

Potentiometer
RV1 . . . . 10k/C pot

Capacitors
C1. . . . . 10p ceramic
C2. . . . . 40p trimmer
C3. . . . . 100p ceramic
C4 - C6 . . . 1μ solid dipped tantalum

Semiconductors
D1 - D3. . . OA95
D4,5 . . . . 1N914

Miscellaneous
RFC1. . . . Any moulded RF choke, 1mH or more (value not critical).
SW1. . . . . C & K switch type 7211 (see text)
M1 . . . . . 50 μA meter, T.E.W. type, 2k resistance.
T1. . . . . 40 turns of 35 gauge B & S enamelled wire, around circumference of Neosid toroid type 28-511-31, 12.7 mm o.d., 6.35 mm i.d., 3.18 mm thick, F14 material (see text)
Coax sockets . . . SO239 or other type to suit
Case. . . . . Horwood type 34/2/D (100 mm x 75 mm x 50 mm).
PC board . . ETI 139
Two 25 mm long bolts with three nuts and two lock washers each; nuts and bolts for coax sockets (if required); length of RG58 coax; 6 mm dia. sleeving; hookup wire, etc.

How it works – ETI 139

The reflectometer employs a "current transformer" having an electrostatically-shielded primary with a high-ratio secondary winding driving a low value load resistance.

A short length of coaxial cable, passed through a ferrite toroid, forms the primary with the braid connected so as to form an electrostatic shield.

The secondary of the current transformer consists of a winding around the circumference of the toroid, coupled to the magnetic component of the 'leakage' field of the short length of coax cable.

The secondary drives a centre-tapped resistive load (R2/R3) connected to a voltage sampling network (C1-C2/C3) tapped across the RF input such that sum and difference voltages will appear across the ends of the current transformer (T1) secondary winding.

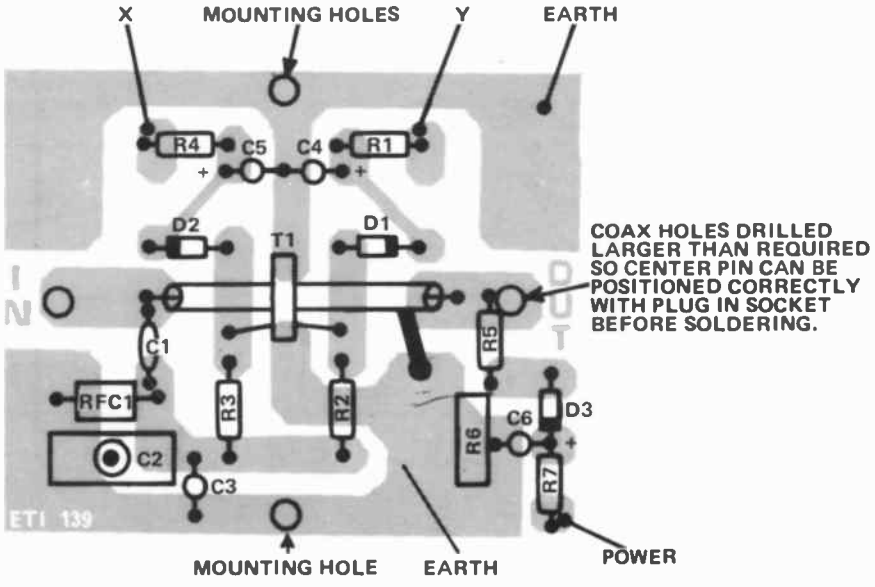
Diodes D1 and D2 rectify the sum and difference voltages from the secondary of T1, RF and audio (modulation) bypassing being provided by C4 and C5. The RF choke, RFC1, provides a low-resistance DC return for the signal rectifiers, D1 and D2.

The power measurement facility is obtained by tapping off a portion of the RF voltage on the line via R5 and R6, and rectifying this with D3. Capacitor C6 provides RF and audio (modulation) bypassing.

As the load on the rectifier is so light – R7 being 100 k and the meter being 2 k, peak power is measured.

Diodes D4 and D5 provide protection for the meter.

Fig. 2. Component overlay for the pc board. Note that, contrary to the usual practice, the components are mounted on the copper side of the board.



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The impedance discontinuities introduced by the prototype are well inside the basic accuracy capability of the meter movement! The real part of the instrument's impedance is within 5% of the nominal 50 ohms – most of this is probably due to connectors and construction discontinuities.

The variation in the real part of the impedance is within +/- one ohm across the frequency range of the instrument, and can be essentially ignored.

The reactive (imaginary) component of the instrument's inherent impedance is negligible up to 20 MHz when it begins to become slightly capacitive.

The overall impedance decreases rapidly above 100 MHz.

Sensitivity and sensitivity bandwidth of the prototype is excellent. The half-power points of the sensitivity bandwidth of the reflectometer are at approximately 350 kHz and 25 MHz.

Full-scale deflection at 27 MHz requires 0.8 watts into 50 ohms. Mid-band sensitivity is under half a watt!

Modifications

For higher power applications, the basic sensitivity of the reflectometer can be reduced by one of several methods, or a combination.

If you are working with powers around 20 to 50 watts, R2 and R3 can be reduced to 47 ohms. For higher powers, the number of turns on the toroid can be reduced, and R2/R3 further reduced in value. As a guide, reduce the secondary of T1 to 20 turns and R2, 3 to 47 ohms. Everything else remains unchanged. This should suit power levels of 200 watts and higher.

Other types of coax sockets can be used, such as the BNC, type N or the inexpensive Belling-Lee sockets. No modifications to the pc board are necessary, however, mounting details of the sockets and board will need to be altered to suit.

The basic reflectometer construction is so simple and inexpensive that several can be built and installed to provide remote SWR/RF-output monitoring of antenna installations.

The RF portion can be mounted at a convenient place and the reflectometer output leads X and Y taken to remote metering facilities. Power output measurement circuitry is probably superfluous in these circumstances.

Protection circuitry for transceivers and power amplifiers may be simply realised using the basic reflectometer circuit and activating protection devices by comparing the output voltages of D1 and D2.

Swept VSWR measurement can be accomplished using the basic reflectometer circuit. The differential output from D1/D2 can be used to drive the vertical axis of a CRT display (via suitable amplification), the horizontal axis being driven by the sweep voltage of a voltage-controlled signal generator. Voila! - swept VSWR measurements.

Accurate SWR measurements for VSWR values below 2:1 can be made by driving an expanded-scale differential voltmeter circuit that measures the output difference between D1 and D2. This technique is well illustrated in reference 2.

This type of instrument is particularly useful when making VSWR performance plots of antennas over a narrow bandwidth (providing they closely match 50 ohms in the first place).

This reflectometer technique can also be used to measure power. However, the authors opted for the diode RF voltmeter method as it is somewhat more versatile, and is unaffected by the sensitivity bandwidth of the toroidal current transformer. See the two references for more details.

The sensitivity bandwidth may be shifted up in frequency by a decade or more, such that it rolls off around 1 MHz and 50 MHz, by employing a toroid for T1 of the same dimensions but made of F25 material.

References

Whilst not the 'definitive' texts on this type of reflectometer, these two references provide good practical sources of information.

1. "Frequency Independent Directional Wattmeters"; P.G. Martin, Radio Communication (RSGB journal), July 1972.
2. "Test Equipment for the Radio Amateur", H.C. Gibson G8CGA, published by the RSGB, 1974.

Note: The manufacturers of the toroid, Neosid Limited (Australia), are located at 23/25 Percival Street, Lilyfield NSW. However, components suppliers such as Davred and Dick Smith's may have them in stock *– but accept no substitutes!*

Fig. 3. The meter, sensitivity pot and switch connections. Leads X and Y go to D2 and D1 respectively, while the lead marked 'POWER' goes to R7. Refer to figure 2.

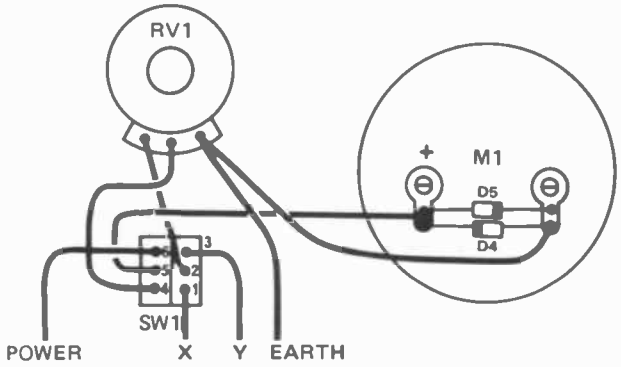
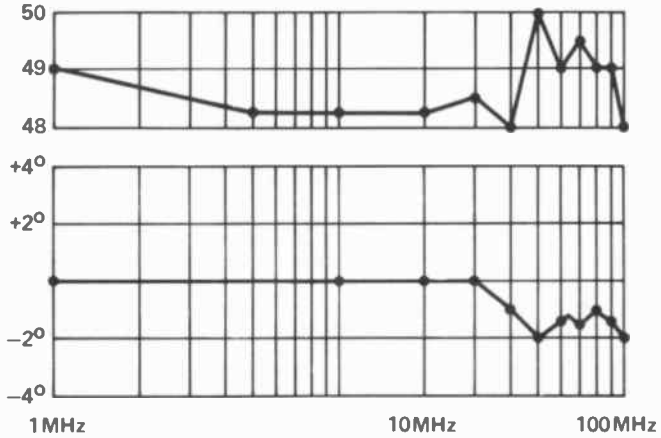


Fig.4. Top: real or resistive component of the prototype's inherent impedance. Lower. Reactive component.



World Radio History

RF SIGNAL GENERATOR

simple unit for servicing AM receivers

eti PROJECT 129

AN RF SIGNAL generator is an invaluable instrument for AM radio servicing and alignment — it greatly simplifies alignment and allows each stage to be checked for gain and frequency response.

Three types of signal are required for these purposes. Firstly, we require an audio signal to check that part of the receiver from the volume control (after the detector) to the speaker. Secondly, we need a modulated RF signal at 455 kHz (430 to 480 kHz available for non-standard receivers) for checking and aligning IF stages, and lastly, we need a modulated RF signal in the range 500 to 1600 kHz to check out the RF amplifier and converter.

In addition the level of the generator output should be adjustable so that AGC action may be checked out, and so that optimum levels may be chosen for servicing and gain checks. All the above requirements are met by the ETI 129 generator and, since only one of the available signals is used at any one time, a common level control is used for all these outputs.

In our generator the provision of IF frequencies from 430 to 480 kHz, as well as catering for non-standard receivers, allows receiver IF selectivity to be checked.

CONSTRUCTION

The prototype instrument was mounted in an aluminium box having external dimensions of 145 x 115 x 90 mm. Layout of the circuitry is important and for this reason the printed-circuit board layout provided should definitely be used. Take care when assembling components to the printed-circuit board to correctly orientate capacitors C9, C11 and C15, transistors Q1 to Q4 and diode D1.

The variable capacitor is mounted onto the component side of the printed-circuit board but spaced from it by about 2 mm (an oversized nut may be used). The mounting of the board and variable capacitor assembly to the front panel and reduction-drive assembly may best be understood by referring to Fig. 3. Note that the board is mounted by four standoffs and that rubber grommets are used to allow the board to move slightly — for this reason the screws should not be tightened too much. This method is used to avoid the expense of using a flexible drive to the variable capacitor.

The six-to-one slow-motion drive is mounted to the front panel by two 15 mm long bolts. The drive is spaced back from the front panel by 4 mm long spacers.

The remaining controls are mounted straight onto the front panel as shown in the photograph.

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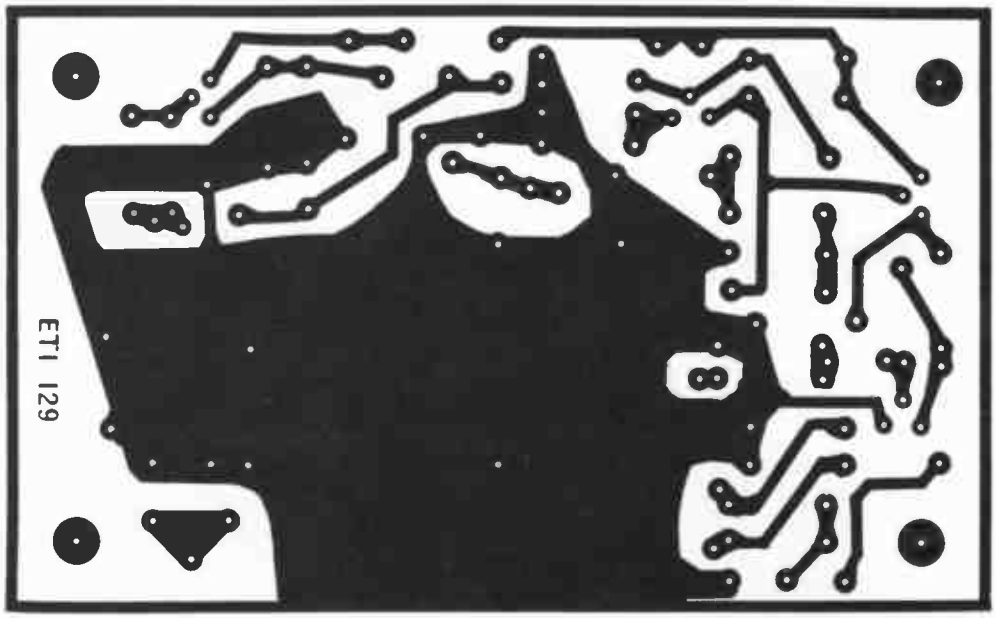
RF SIGNAL GENERATOR



Printed-circuit board layout.
Full size 129 x 80 mm.

CALIBRATION

High Range. Using a conventional AM receiver tune to a station at the top end of the frequency band. Set the pointer of the RF generator to indicate the frequency of the station being received and couple the generator to the receiver

Adjust capacitor C3 until the signal from the generator can be heard interfering with the station. This will take the form of a whistle which, as C3 is tuned, will go from a high frequency to a low frequency and then back to a high frequency again. The correct tuning point is where the frequency is at its lowest, i.e. in the middle. The level of the generator signal may have to be increased to obtain the correct point with accuracy. This procedure is called

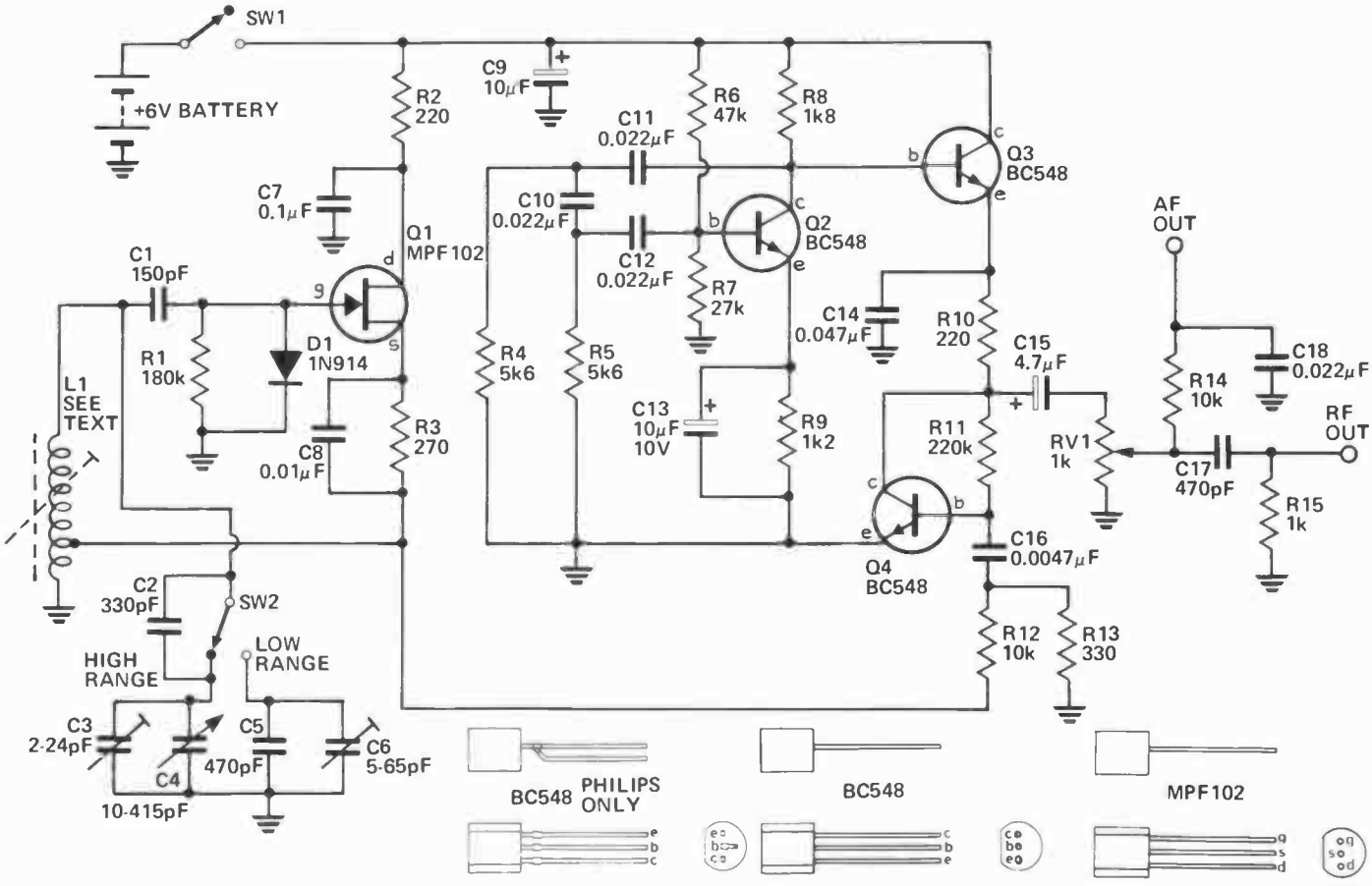


Fig. 1. Circuit diagram of the modulated RF generator.

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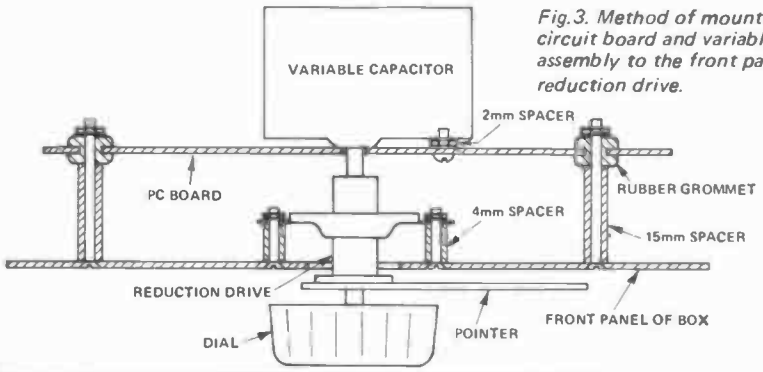

Fig.3. Method of mounting printed-circuit board and variable capacitor assembly to the front panel and reduction drive.

PARTS LIST — ETI 129

R2,10	Resistor	220	¼W 5%	C10,11	Capacitor	0.022µF	polyester
R3	"	270	" "	C12,18	"	0.022µF	polyester
R13	"	330	" "	C14	"	0.047µF	polyester
R15	"	1k	" "	C7	"	0.1µF	polyester
R9	"	1k2	" "	C15	"	4.7µF	10V electro-lytic
R8	"	1k8	" "	C9,13	"	10µF	10V electro-lytic
R4,5	"	5k6	" "				
R12,14	"	10k	" "	Q1	Transistor	MPF102	or similar
R7	"	27k	" "	Q2,3,4	"	BC548	or similar
R6	"	47k	" "				
				D1	Diode	IN914	or similar
R1	"	180k	" "				
R11	"	220k	" "	SW1	Switch	SPST	toggle
				SW2	"	SPDT	toggle
RV1	Potentiometer	1k Lin	rotary.				
				L1	Inductor	See table 1.	
C3	Capacitor	2-24pF Phillps 2222-808-00006		PC board ETI 129			
C6	"	5-65pF Philips 2222-808-01001		Metal box 145 x 115 x 90 mm			
				Front panel			
C1	"	150pF ceramic		6 to 1 Reduction drive.			
C2	"	330pF ceramic		Four rubber grommets			
C4	"	10-415pF Roblan variable		Four 15mm long spacers*			
				Two 4mm long spacers*			
				Two 2mm long spacers*			
C5,17	"	470pF Ceramic		Three terminals (red, black, green)			
C16	"	0.0047µF polyester		Nuts & bolts etc.			
C8	"	0.01µF polyester		*Spacers may be cut from longer sections.			

'zero beating'.

Now tune the receiver to a station at the low end of the band. Again set the pointer of the RF generator to the frequency at which the station operates and adjust the slug of L1 for zero beat in the same manner as for the high end.

Repeat the procedure for both the high and low ends of the band until there is no change at either end.

Low Range. The low range should be calibrated after the high range calibration has been completed.

First set C6 to mid position. Then tune in a station on a broadcast receiver that lies somewhere between either 860 and 960 kHz or 1290 and 1440 kHz. These two bands are twice and three times the generator IF band respectively. That is, we are working on the second or third harmonic of the generator respectively. Divide the actual frequency of the tuned-in station by two (for stations between 860 kHz and 960 kHz) or by three for stations between 1290 and 1440 kHz. Now set the pointer on the RF generator to this frequency. Adjust the capacitor C6 for zero beat as detailed for the high range.

Refer to any standard textbook for alignment procedure for AM receivers.

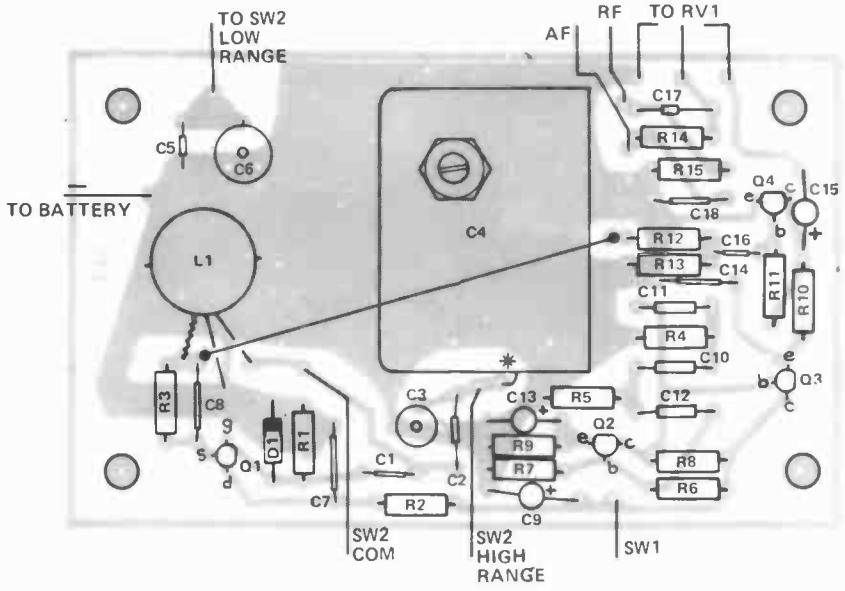

Fig. 2. Component overlay for the RF generator. Note the wire link between R12 and C8 which should be installed before fitting C4. Also note the connection from C4 to the board where shown by the asterisk.

HOW IT WORKS — ETI 129

The circuit may be sub-divided into three basic sections. These are:–

a) RF or carrier oscillator.

b) AF or modulation oscillator.

c) Modulator and buffer amplifier.

a) Transistor Q1 is connected as an Hartley oscillator. The positive feedback necessary for oscillation is provided from the source terminal of Q1 back to the gate via coil L1. The frequency of oscillation is determined by coil L1 in conjunction with capacitors C2 through C6.

Two ranges are provided, 500 kHz to 1600 kHz with L1, C3 and C4; and 430 to 480 kHz with L1, C2, C5 and C6. Diode D1 is used to develop a negative bias across R1 which thus limits the level of oscillation, and hence prevents damage to the gate of Q1.

b) Transistor Q3 is connected as a phase-shift oscillator. The network C10,C11, C12, and R3, R4 provides about 180° phase shift of the signal at the collector of Q3, and the feedback to the base of Q3 is therefore positive – causing oscillation. The frequency of oscillation is about 600 Hz.

c) Transistor Q4 is a class 'A' amplifier which is biased by the half-supply method (R10 and R11) the operating supply being obtained from emitter-follower ,Q3. The output of Q3 is the sine-wave from the phase-shift oscillator. Because of R11 any change at the junction of Q3 and R10 causes a corresponding change in the emitter current of Q4. The emitter current of Q4 therefore varies at the rate of 600 Hz. The emitter resistance of a transistor depends on the emitter current of that transistor and the gain depends on the ratio of the collector load, R10 to the emitter resistance. Since the emitter resistance is varying at 600 Hz, the gain of the transistor will also be varying at 600 Hz and so the RF signal fed to the base of Q4 from Q1 by C16 is modulated by the audio signal.

The signal across R10 is fed to RV1 by C15 and this signal consists of two components – the modulated RF and the audio tone.

After attenuation by RV1 the signals are separated by high and low pass filters to the AF and RF outlets.

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RF SIGNAL GENERATOR

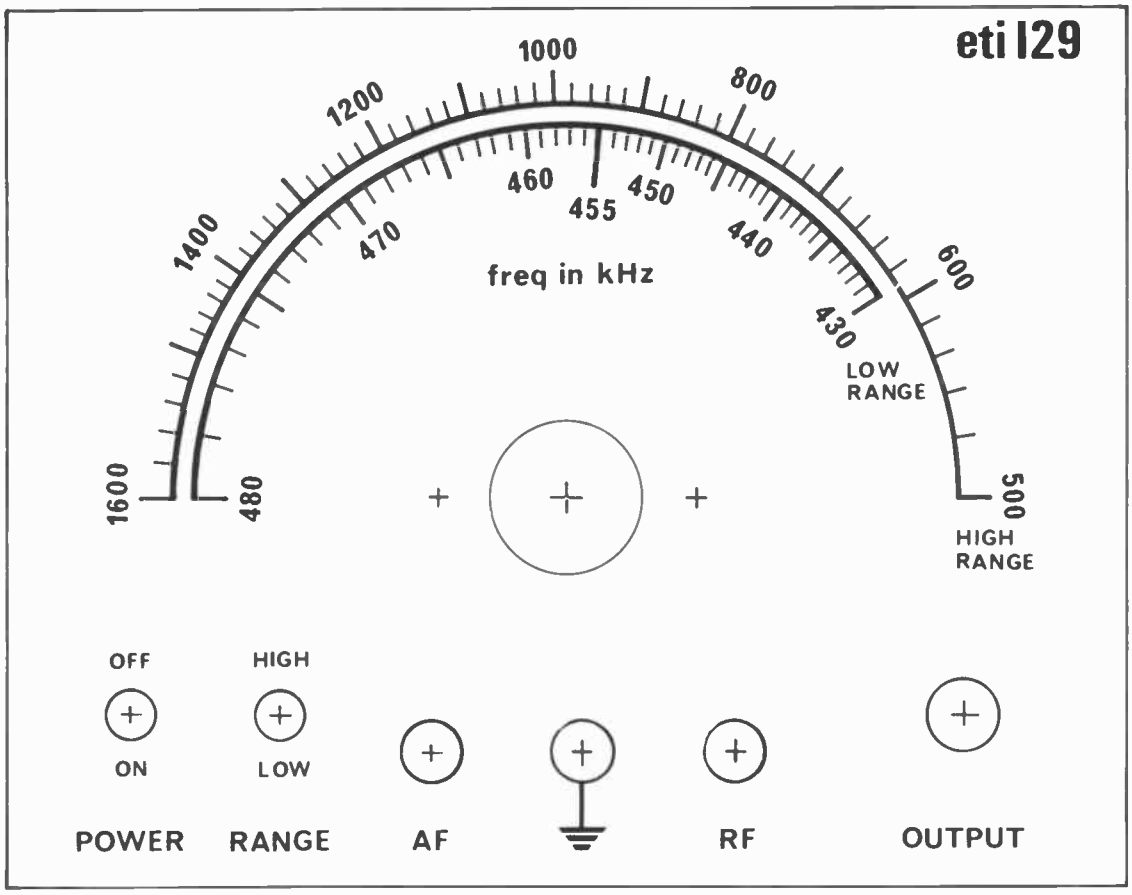


Fig. 4. Front panel artwork. Full size 148 x 116 mm.

COUPLING TO RECEIVER

Method 1. To ferrite rod coil. Connect one end of a length of ordinary hook-up wire to the RF OUT jack and then wrap about two turns of the other end of the wire around and over the aerial coil on the ferrite rod.

Method 2. To an IF amplifier. Connect a wire to the RF OUT jack and to its other end connect a 0.001 capacitor and a 1 k resistor in series. To inject the signal into the IF stage just connect the free end of the resistor to the base of the IF stage transistor.

In both the above methods if insufficient signal level is available an earth connection may also have to be made between the generator and the receiver.

Method 3. Audio testing. Use a length of wire as before but with a series capacitor of about 0.47μF. Note that an earth connection will definitely be required in this case. Once again the best place to inject a signal is straight into the base of the transistor.

Internal view of the generator.

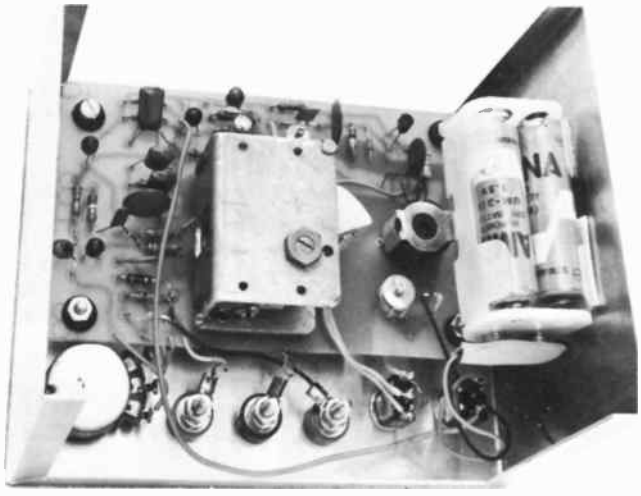


TABLE 1

L1	20 turns 0.5 mm enamelled copper wire tapped at four turns from grounded end.
CORE	Philip potcore P18 series, material 3B7 or 3H1, μe = 220. Part No 4322 – 022 – 24280 or 4322 – 022 – 24080
FORMER	4322 – 021 – 30270
ADJUSTOR	4322 – 021 – 31080
CLIP	4307 – 021 – 20000

One each of core, former, adjustor and clip required to assemble one complete coil.

World Radio History

LOGIC TRIGGER

Debug complex logic circuitry with this unit.

WHEN USING AN oscilloscope to examine or fault find digital circuitry, it is often desirable to see what happens just before a pulse or edge occurs. An example of this is when measuring the propagation delay in a ripple counter. Here it is easy to trigger on the last output but the edge of the counter input which initiated the change in the output may have occurred over 100 ns earlier. Even with the delay line built into modern oscilloscopes the edge is too early to see.

Triggering on the input waveform allows this edge to be seen but if the output pulse occurs only once every thousand or so pulses it will not be seen. With this unit, the output of all the stages in the divider can be examined and a pulse can be generated anywhere in the cycle. By selecting a pulse very close to, but before, the edge in question and using it to trigger the oscilloscope (use ext trigger) both the clock waveform and output waveform can be seen.

With the advent of microprocessors it has become increasingly difficult to fault find as things happen (e.g. the CE input to a memory may go low) only when a particular address is given. As the address bus is always in motion it is almost impossible to trigger the scope on any one address. Again with this unit the address bus is interrogated along with the necessary write or read lines, and its output can be used to trigger the oscilloscope only when the correct sequence is received.

SPECIFICATION - ETI 141

Modes	Asynchronous or synchronous
No. of inputs	12 address, 1 clock
Loading	
address	0.4 UL (TTL)
clock	0.4 UL (TTL)
Pulse extension mono	10 ms
Pulse indication	LED
Minimum pulse detectable	<40 ns
Propagation delay	<45 ns
Trigger (synchronous)	positive or negative edge of clock input
Set up time (synchronous) address to clock	<40 ns
Output	logical "1" when input agrees with switch setting and/or clock (synchronous only)
Power requirement	+5V @ 50 mA

World Radio History

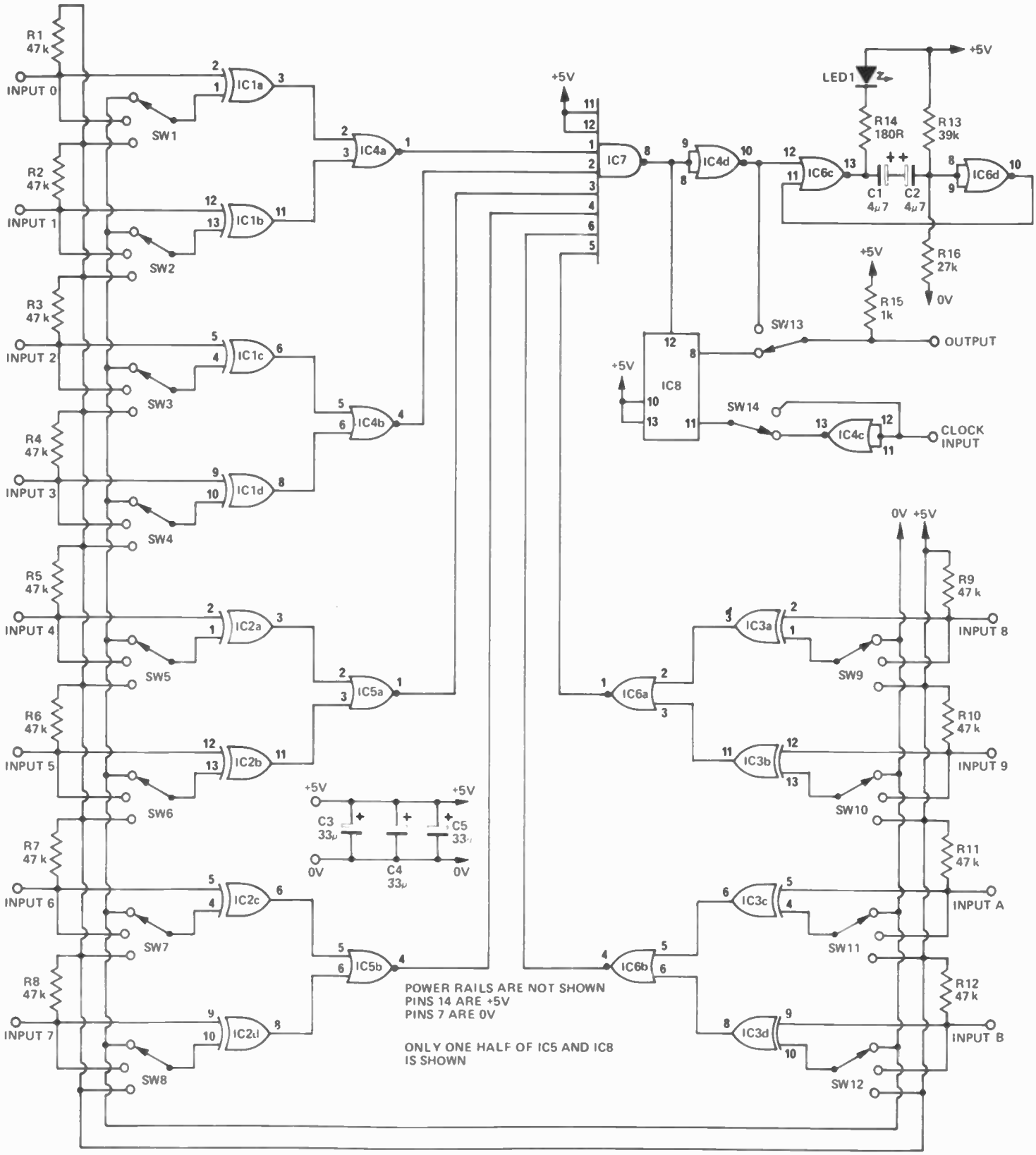


Fig. 1. Circuit diagram of the Logic Trigger.

World Radio History

PARTS LIST – ETI 141

Resistors all ½ W, 5%
R1–R12 . . . . 47k
R13. . . . . 39k
R14. . . . . 180R
R15. . . . . 1k
R16. . . . . 27k

Capacitors
C1,2 . . . . . 4μ7 25V electro
C3–C5 . . . . . 33μ 16V tantalum

Semiconductors
IC1–IC3 . . . . 74LS86
IC4–IC6 . . . . 74LS02
IC7 . . . . . 74LS30
IC8 . . . . . 74LS74
LED 1 . . . . . Red LED

Miscelaneous
PC board ETI 141
Twelve 3 position slide switches
Two 2 position slide switches
Front panel
Box to suit

HOW IT WORKS - ETI 141

The twelve inputs are compared to the levels set on the slide switches SW1-SW12 by the exclusive OR gates IC1-IC3. These ICs have a high output only if the two inputs differ. If they are the same, either both low or both high, the output will be low. If the two inputs are joined together, as when the switches are in the don't care position, the output will always be low.

The outputs from the exclusive OR gates are combined in pairs by the NOR gates IC4-IC6. If the 12 input signals match the preset selection, the output of all 6 NOR gates will be high. If any one is not in agreement with the selection one or more of the NOR gates will have a low output.

These NOR gate outputs are combined by IC7 which is an eight input NAND gate. The output of this gate will low only if all 12 inputs match. The output of this IC is inverted by IC4/d to provide the asynchronous output.

This output also triggers the monostable formed by IC6/c and IC6/d. This gives a 10 ms long pulse to light the LED indicating a pulse was received. If it is a steady state signal the LED will stay on.

The output of the NAND gate, IC7, also joins the data input of IC8 (D type flip flop). This IC is toggled on the positive edge of the clock waveform transferring the data to the output. This is the synchronous output. To allow for either positive or negative synchronization an inverter is used on the clock input and either polarity can be selected by SW13.

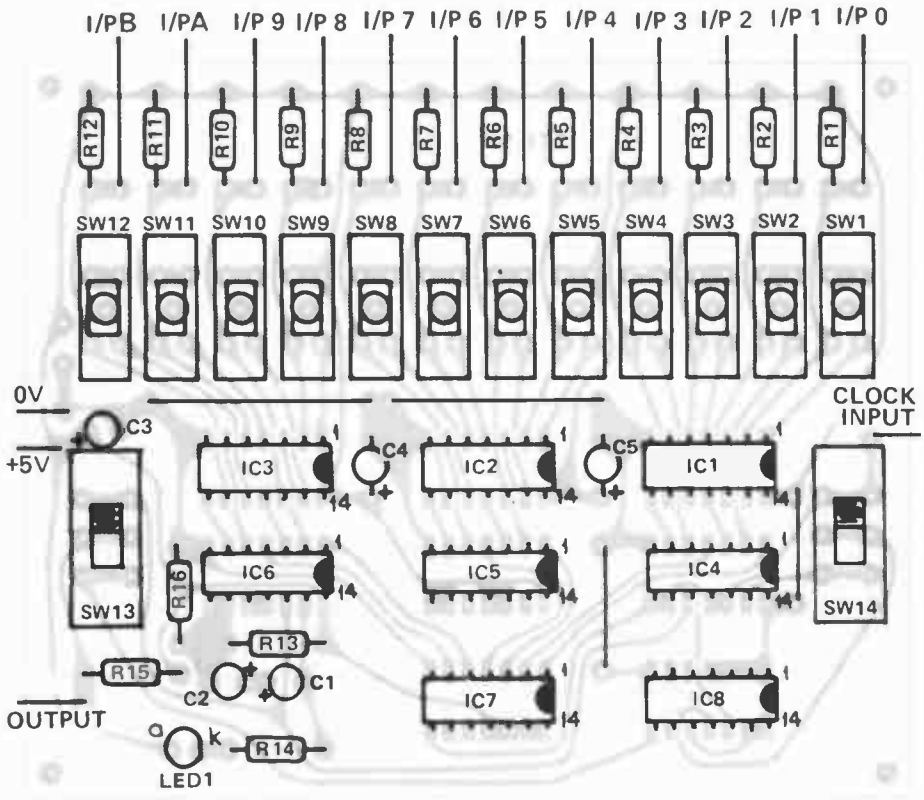


Fig. 2 Overlay of the PCB

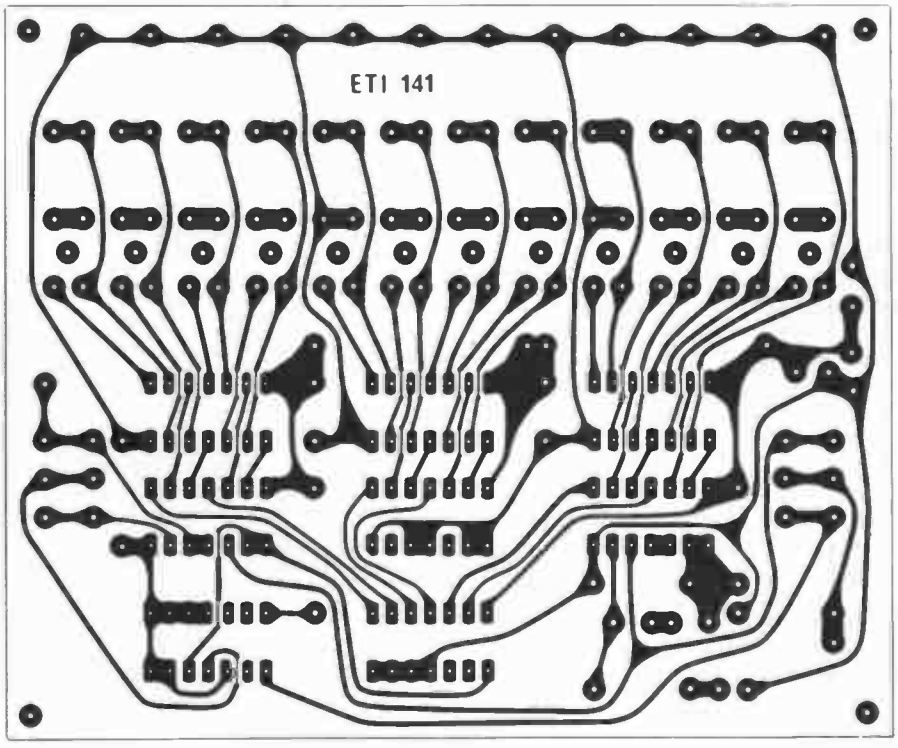


Fig. 3 PCB pattern shown full size.

World Radio History

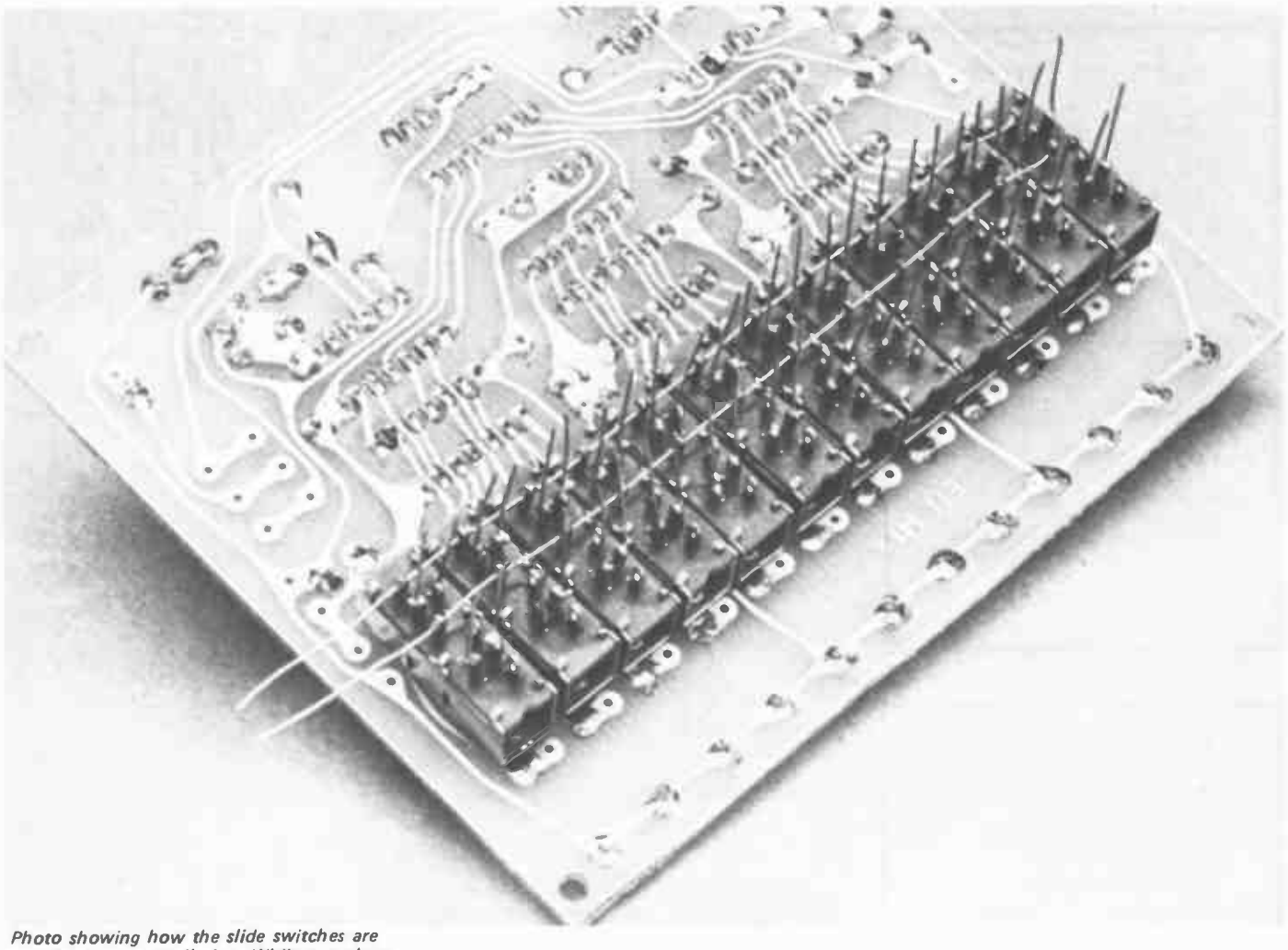
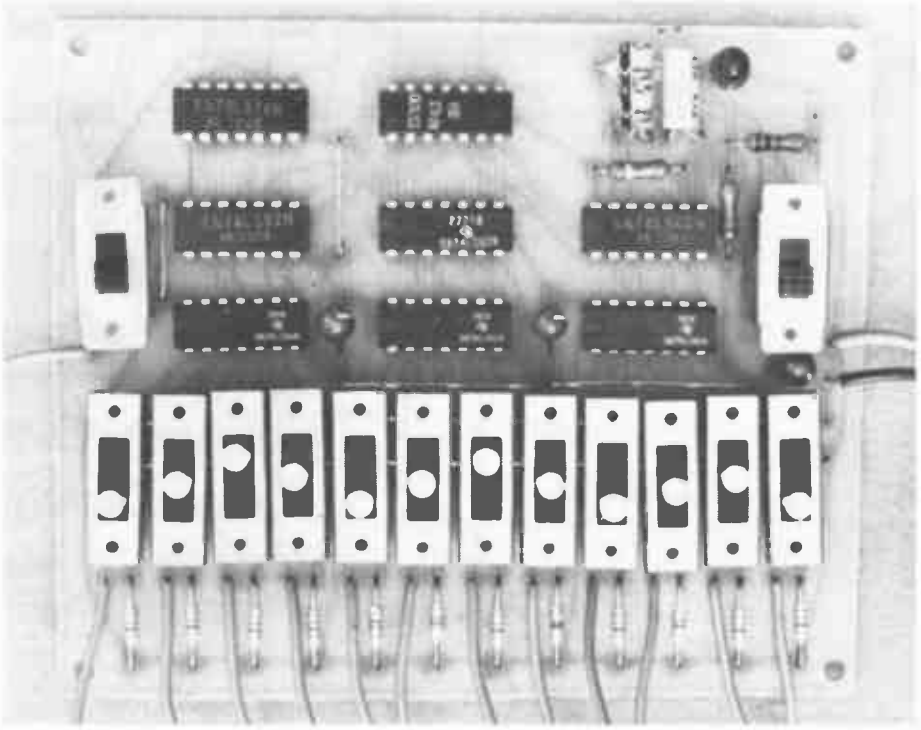


Photo showing how the slide switches are wired prior to installation. While our photo shows them on an assembled pc board it is best if they are wired before the board is assembled.



Construction

We mounted all the components on the pc board including the switches. The only difficult (fiddly) bit is the wiring of the three position slide switches which have to be preassembled before fitting to the pcb. The wiring is shown in fig.3.

To aid this we have provided 12 holes in the pcb the size of the toggle of the switches; if the switches are initially placed upside down in these holes the board will act as a template to provide the correct spacing. We have also used two wires of the second pole of the switch to provide mechanical support. While only a single pole switch is needed the only ones readily available (from Dick Smith) are two pole.

The switches can now be mated to the pc board with the two longitudinal wires being terminated in the holes provided at the end of the switch bank.

World Radio History

Project 148

Versatile logic test probe

If you work or experiment with logic circuitry this project should be invaluable for debugging circuits. Inexpensive to build, it may be used both with TTL and CMOS circuitry, and indicates HI or LO conditions as well as pulse trains above 1 MHz. It will also detect short, isolated pulses having widths down to 500 ns.

Dr P.M. Kelly

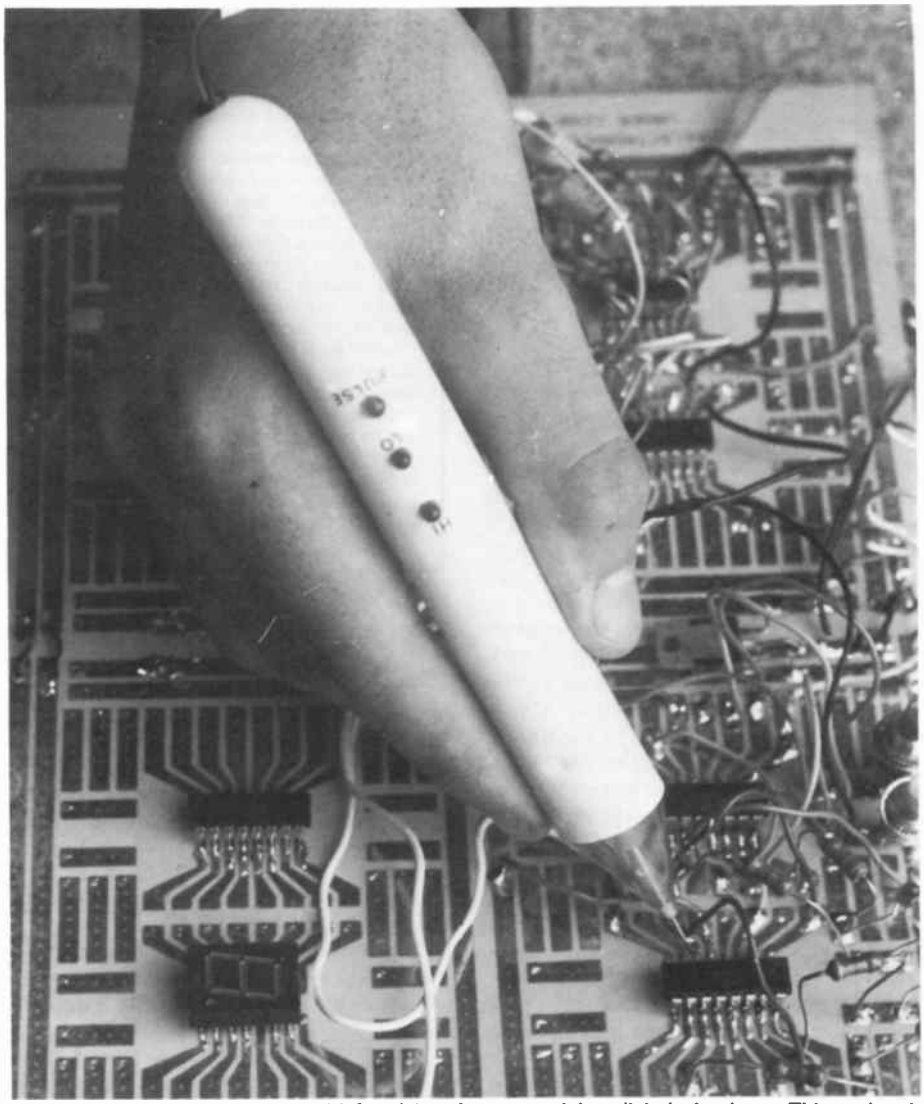
INTEREST in digital electronics has grown rapidly in the past few years with the advent of microprocessors and large scale integration. The most essential test instrument for experimenting with digital circuitry is a logic probe.

In its most basic form this should provide an indication of the logic level at any point in a circuit without overloading the section being tested. Other desirable features are the ability to follow high frequency pulse trains (preferably over 1 MHz) and to detect isolated, narrow pulses less than 1 μsec in width. Finally, the instrument should be compatible with both TTL and CMOS ICs and be able to operate from a wide range of supply voltages (say five to 15 volts).

Commercial logic probes that satisfy all these requirements are available, but they invariably cost over $30. The probe design described here offers comparable performance for less than $5, combined with an excuse to enjoy a good cigar – a cigar tube is used for the case!

Indication is by means of three LEDs. Two red LEDs indicate either a HIGH or a LOW condition on the point under test, a green LED is used to indicate that a pulse train is occurring.

The circuit uses a single CMOS IC and a handful of resistors and capacitors. The components are mounted on a small pc board and housed in a tubular case such as an aluminium cigar tube or a length of plastic conduit. The power is supplied from the actual circuit under test and the performance characteristics of the prototype are described in the specification listed here. ▶

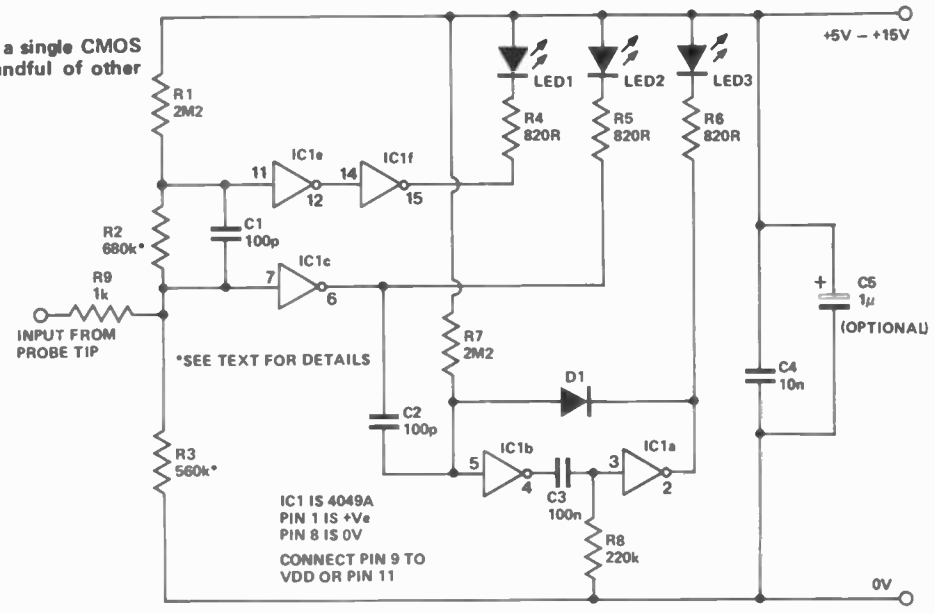


A logic probe is an invaluable aid for debugging or servicing digital circuitry. This project is inexpensive and easy to build.

World Radio History

Project 148

The circuit is simple, involves a single CMOS IC, three LEDs and a handful of other components.



SPECIFICATION ETI-148

- TTL or CMOS compatible
- Supply voltage: 5 to 15 volts
- Input impedance: over 400k
- Indicates HIGH (1), LOW (0) or floating states
- Follows high frequency pulse trains – over 1.5 MHz
- Detects single pulses down to 500 nsec in width, and stretches these to 15 msec.
- Relative brightness of HIGH/LOW LEDs indicates duty cycle of pulse trains.

HOW IT WORKS ETI 148

Three of the six inverter/buffers in IC1 are used in the high/low detection circuit. IC1c is connected to the probe tip via R9. When the input goes HIGH (logic 1), IC1c output goes low and illuminates LED 2 through R5. Similarly when the input goes LOW (logic 0), the series pair IC1e and f illuminate LED 1 through R4. The resistor network R1, R2 and R3 ensure that the outputs of both IC1c and IC1f remain high when the input is 'floating'. C1 is connected across R2 as a 'speed-up capacitor' to maintain a sharp pulse shape into IC1e and so improve the ability to follow high frequency pulse trains (over 1MHz)

The two inverters IC1a and b form a monostable circuit that stretches short pulses (less than 500 nsec) out to 15 msec (0.7RC) using C3 and R8. The input of the monostable comes from the output of IC1c and is isolated from the DC level of this output by C2. The combination of R7 and D1 normally holds IC1b input high. When a negative going pulse is fed into IC1b through C2, the output goes high, forcing IC1a to go low and illuminate LED 3. Diode D1 ensures that the input to IC1b is kept low (0.7V above zero) so long as the output of IC1a remains low. This prevents subsequent pulses from re-triggering IC1b until the monostable itself retriggers via discharge of C3 to earth through R8, and allows IC1a output to go high, switching off LED3.

Capacitors C4 and C5 (optional) confer immunity to spikes or pulses in the supply lines, which are taken from the circuit being tested.

Construction

A printed circuit board is recommended for this project to provide consistent performance characteristics.

Before attempting to mount the components on the printed circuit board check to see that it fits easily into the case. The board must be a loose enough fit to allow it to be moved up and down within the case over a range of at least 5 mm. (Refer to the diagram).

If this is not possible, the width of the board can be reduced slightly with a file or coarse sandpaper, taking care not to remove too much or to damage the copper portions of the board.

The other alternative is to use a larger case – buy a bigger cigar! This movement within the case is necessary so that the LEDs can be juggled into position in the holes in the casing (see later).

Mount the wire links, the resistors and the capacitors on the pc board, keeping all components as close to the board as possible. Note that C3 is mounted on the underside of the board. Next, install the three LEDs. The height of the LEDs above the pc board must be such that the assembly will slide into the case with the board pushed down against the bottom of the case (see diagram). For a 20 mm diameter case this height should be about 12 mm. If the LEDs are not high enough, then it will not be possible to push the assembled board up into a position where the LEDs project through the holes in the case.

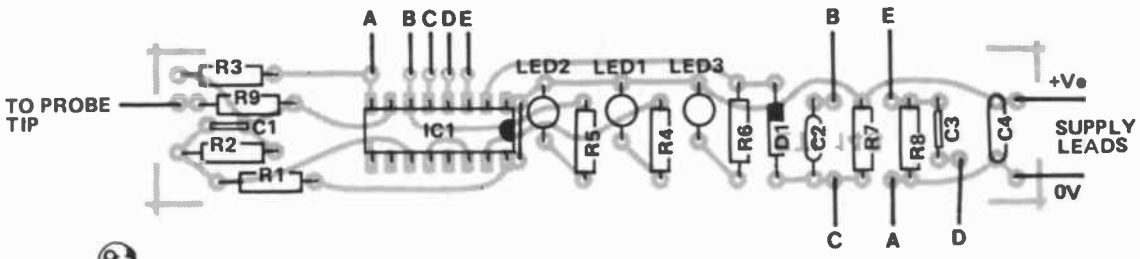
Next, add the power leads (without clips or E-Z hooks at this stage) and the 10 cm wire to the probe tip. Last of all solder IC1 into position, observing all the usual precautions – shorted pins, heat sink, earthed soldering iron, pins 8 and 16 soldered first.

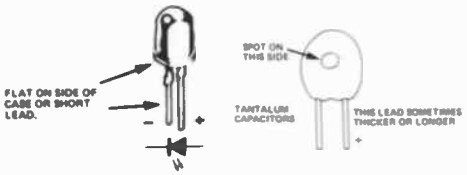
The probe tip housing on my prototype was turned from perspex and a 2 mm hole drilled through the centre. The probe tip wire is soldered to the end of a darning needle which is cemented into the housing with epoxy, allowing the needle to project about 15 mm beyond the end of the housing. It is not necessary to use a perspex cone, turned up as I have it. A flat-faced plug of a suitable material will suffice equally well.

Drill the 3mm holes for the LEDs at 10 mm intervals, starting 75 mm from the front of the case. The hole for the supply leads is drilled in the back of the case and fitted with a small rubber grommet (or plastic LED housing) to prevent the case rubbing through the insulation on the leads.

Before mounting the assembled pc board in the case check the circuit for dry joints, solder bridges, incorrectly mounted components, etc. Then test the device as follows. Connect to a five volt supply and observe the three LEDs. None should light with the probe tip isolated. If the LOW LED (LED 2) comes on or flashes, then R2 is too small and must be replaced by a slightly larger resistor (say 820k). Touching the probe tip with the fingers may cause LED 2 to light, but this should go off when the tip is isolated. Touching the probe tip to either supply rail should light the appropriate LED, with the

World Radio History

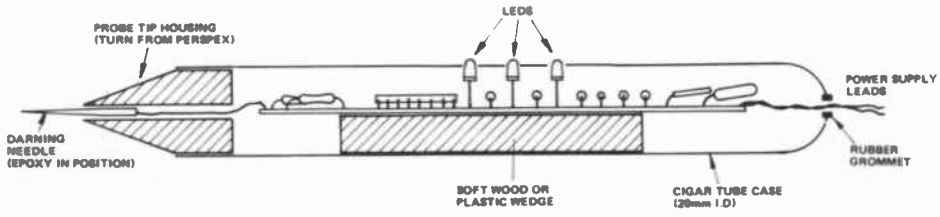


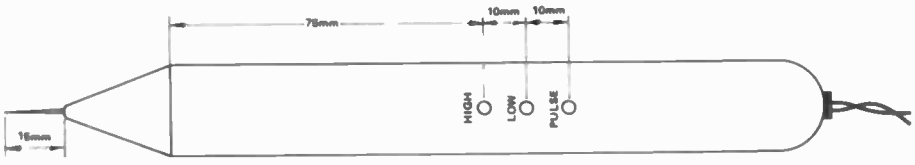


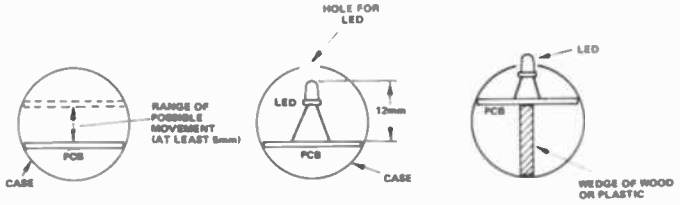
NOTE
C5 IF USED IS MOUNTED ACROSS C4 (OBSERVE POLARITY)

CONNECT RESPECTIVE LETTERS TOGETHER ATO A B TO B etc.

Component overlay for the pc board. Refer to the construction diagrams below for correct assembling of the LEDs.







PARTS LIST – ETI 148

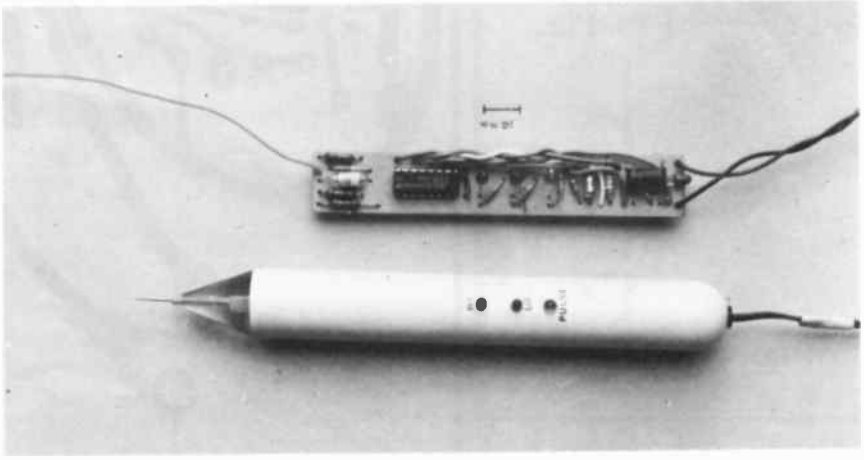
Resistors all ¼W, 5%
R1,7 . . . 2M2
R2 . . . . 680k*
R3 . . . . 560k*
R4,5,6 820R
R8 . . . . 220k
R9 . . . . 1k

Capacitors
C1,2 . . . 100p Ceramic
C3. . . . . 100n Greencap
C4. . . . . 10n Greencap
C5. . . . . 1μ Tantalum (Optional)

Semiconductors
IC1 . . . . 4049A
LED 1,2 . 3mm red
LED 3 . . 3mm green
D1 . . . . 1N4148 (or equivalent)

Miscellaneous
pcb; red and black leads with alligator clips or E-Z hooks;
cigar case (or equivalent) – minimum dimensions 20mm ID, 140mm long;
perspex rod for probe tip housing;
darning needle.

Resistors R2 and R3 may have to be altered slightly (in the range 470 k to to 1M2) to suit the transfer characteristics of IC1 – see text.



The printed circuit board for this project is reproduced on page 128.

These diagrams above, and the picture left show the general construction of the probe and the drilling of the cigar tube or whatever case is used. ▶

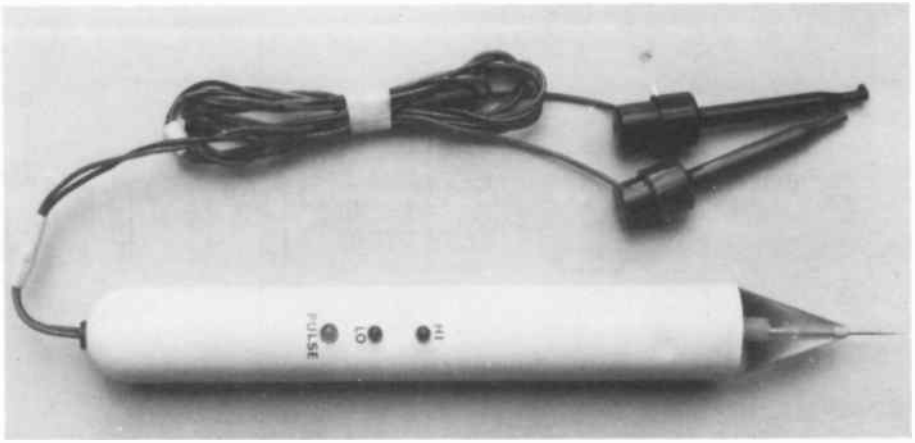
World Radio History

PULSE LED flashing when the tip first touches the positive rail. If the LOW LED does not light when the probe is connected to 0 V, then R2 is too large. Change R2 to 560 k and repeat the sequence above.

Now try a 15 volt supply. Again, all LEDs should be extinguished when the probe tip is isolated. The HIGH LED (LED 1) may glow very faintly. If this glow is too strong, reduce the value of R3 to say 470 k. However, if R3 has to be altered it will be necessary to recheck the circuit at 5 V to see that the low voltage performance is still satisfactory. At 15 volts repeat the process of touching the probe tip to the two supply rails. The results should be the same as in the case of the 5 volt supply, but the LEDs will be considerably brighter.

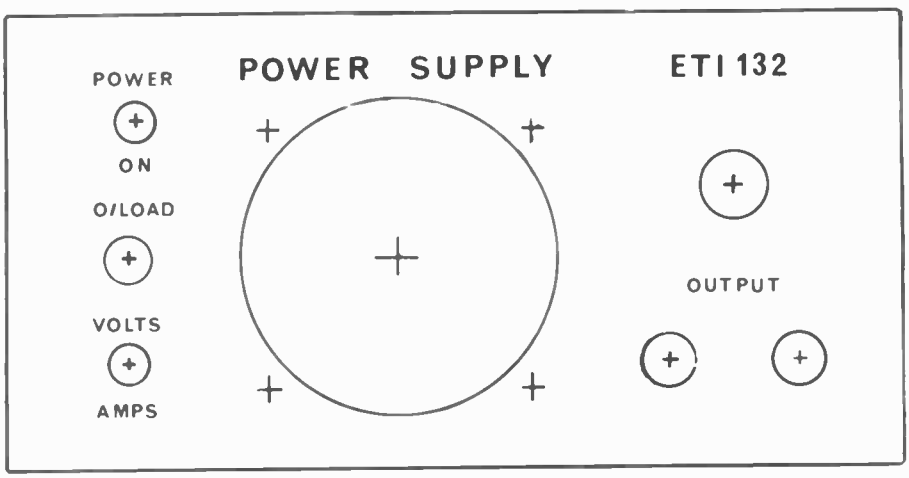
When satisfied that the circuit works correctly mount it in the case. First, cover the edges of the pc board with strips of tape to insulate it from the case and apply a thin smear of epoxy cement around the base of each LED. Feed the power supply leads through the back of the case, followed by the assembled board. Jockey the board into a position where the LEDs are directly under the holes in the case and then push the assembly up into a position so that the LEDs protrude through the holes in the case. The epoxy around the base of the LEDs will anchor them in position. In addition to this means of holding the board in place, a small wedge of soft wood, plastic or similar insulating material can be inserted into the space between the bottom of the board and the case. The probe tip and its plastic housing is then inserted in the front of the case and epoxied in position.

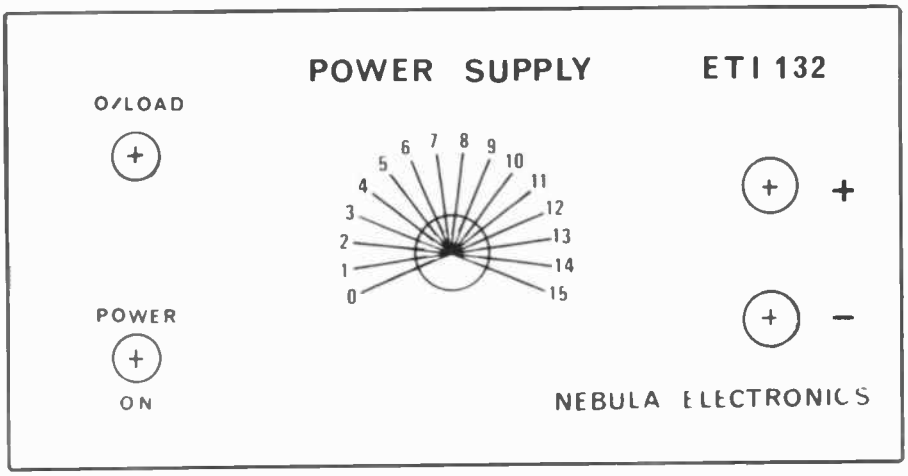
When the epoxy has set, fit the clips or E-Z hooks to the ends of the supply leads, label the three LEDs and give the whole instrument a coat of protective lacquer. The completed logic probe is now ready for use – but don't forget to smoke the cigar! ●



The completed logic probe.

Front panel layouts and pc board for Experimenter's Power Supply project which follows.





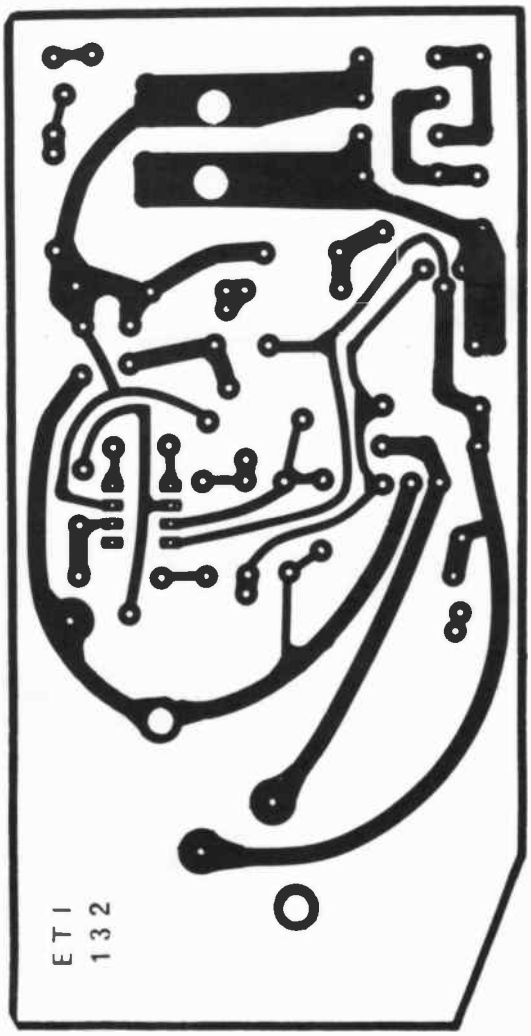


Fig 4. Front panel layouts
Full size 131 x 66 mm.

World Radio History

EXPERIMENTER'S POWER SUPPLY

This power supply is suitable for the experimenter. It has fully adjustable output voltage and current limiting. A single meter can be switched either to voltage or current while an LED will indicate an overload.

THIS ECONOMICAL POWER SUPPLY replaces the ETI 111 supply published some years ago. The 111 gave an output voltage variable between 1.5 and 15 V, this project gives the full range 0 to 15 V. In addition this supply features metering (or you can use the calibrated scale on the second version if you don't have a spare meter) to enable accurate setting of voltage or current.

The 132 is attractively housed in a plastic case and Scotchcal front panels are available to give the unit a professional look.

Construction

Commence by assembling the pc board with the aid of the component overlay diagram. The main filter capacitor C1 is normally a chassis-mounting type, but we mounted this satisfactorily by passing the lugs through the large holes in the pc board, bending them flush with the copper and soldering. Check the polarity of the capacitor before fitting, as it cannot be seen later. The transistor Q3 is fitted, along with its heatsink, with the two mounting screws. No insulation is used between the transistor and the heatsink but pass a small piece of tubing over the base and emitter leads where they go through the heatsink, to prevent shorting. If the meter is not required RV3, RV4 and R10 are not used.

The front and rear panels can now be drilled. Note that the mounting bracket of the transformer has to be cut back about 12 mm on one end to allow it to fit easily. If a scotchcal panel is used it

SPECIFICATION ETI 132	
Output Voltage	0-15 V variable
Output Current	0-1 A
Current Limit	approx 1.2 A
Load regulation	35 mV 0 to 1 A load
Line regulation	20 mV 220 to 260 V input
LED indication of current overload	

World Radio History

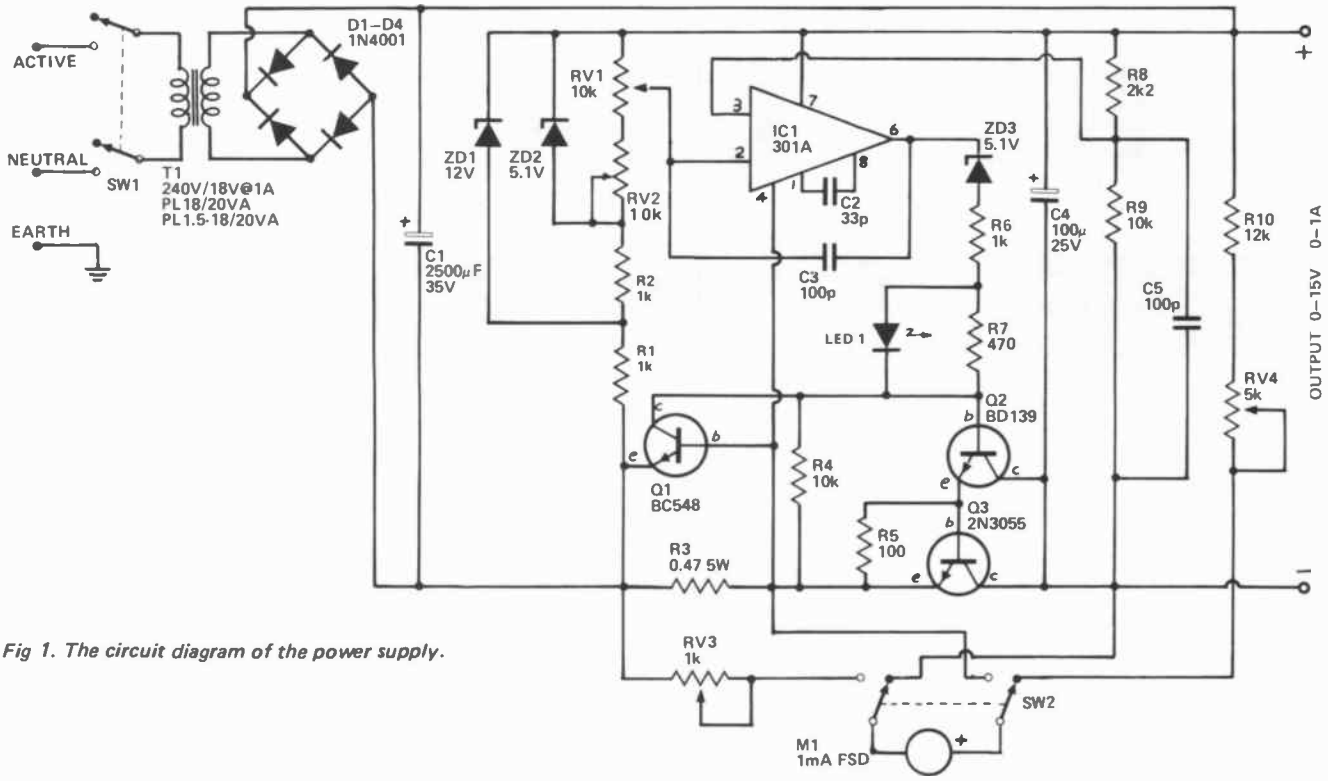


Fig 1. The circuit diagram of the power supply.

How It Works

The 240 V mains is reduced to 18 V in T1. This 18 V ac is then rectified by D1-D4 and filtered by C1 to give about 25 volts dc (on no load). The voltage reference for the supply is ZD2, which gives about 5 V dc. However, due to the large variation in voltage across C1 (caused by load changes) additional regulation is used, incorporating ZD1, and the two circuits give the stability required.

The regulator is a 'series-pass' type with the positive rail common and the negative rail variable. We have done it this way to achieve outputs down to 0 V. The comparator IC (LM301) cannot work with its input less than about 2 volts above the negative rail, but it can work with the inputs at the positive supply rail. However this will not work with all types of op amp – so do not substitute the 301 with a 741 or similar.

The output of IC1 controls the output transistors, Q2 and Q3. A level-shifting zener ZD3 is used in the output of IC1 as its output cannot swing low enough. The output voltage is divided by R8 and R9 and is taken to IC1 which compares it to that set on RV1. IC1 then adjusts the drive to the output stage until the two voltages are the same. RV2 is used to compensate for variations in the voltage of ZD2.

In the event of an overload the voltage drop across R3 will forward-bias Q1, which will bypass current away from the output transistors. This causes the output voltage to fall, the comparator sees this error, and the output of IC1 goes to the positive supply rail (trying to compensate). Q1 however will continue to bypass any extra current, holding the output current constant at about 1.2 A. However, the additional current out of IC1 will forward bias LED 1 and it will indicate the overload.

With such high gain in the circuit additional frequency stability is needed and C3 and C5 provide this. For metering, we simply use a 1 mA movement meter and measure the voltage across the output (via R10 and RV4) and across R3 (current).

Setting Up

1. Without Meter – With this version we rely on the potentiometer to be linear. In practice it is not linear at the two ends of its travel. Calibration is done by adjusting the knob position and RV2.

Set the output to one volt and position the knob to read one volt. Now turn the knob to 15 V and adjust RV2 to give 15 V output. Recheck the 1 V setting and repeat the procedure, if necessary.

2. With Meter – Connect the output to an accurate voltmeter and turn the pot to maximum. Adjust RV2 to give 16 V. Adjust RV4 until the meter reads 16 V (with RV2 switched to volts). Now connect a load and an ammeter. Set 1A on the ammeter and then adjust RV3 until the power supply meter reads 1 A.

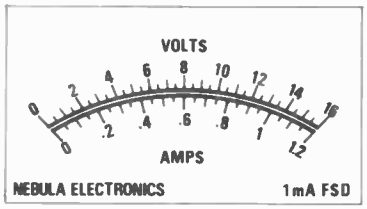


Fig 2. The meter scale used.

World Radio History

PARTS LIST ETI 132

Resistors

R1,2	1 k	½ W 5%
R3	0.47 Ω	5 W 5%
R4	10 k	½ W 5%
R5	100	" "
R6	1 k	" "
R7	470	" "
R8	2k2	" "
R9	10 k	" "
R10	12 k	" "
RV1	Potentiometer	10 k lin rotary
RV2	"	
RV3	"	1 k "
RV4	"	5k "

Capacitors

C1	2500 µ electro type RG
C2	33 p ceramic
C3	100 p "
C4	100 µ 25 V electro
C5	100 p ceramic

Semiconductors

D1-D4	Diodes 1N4001
ZD1	Zener 12 V 400mW
ZD2,3	Zener 5.1 V 400 mW
LED 1	LED with mounting clip
Q1 Transistor	BC548
Q2 "	BD139
Q3 "	2N3055
IC1	Integrated circuit LM301

Miscellaneous

PCB ETI 132
Transformer 240 V – 18 V 20 VA
PI 18/20 VA or PL 1.5-18/20 VA
Case PC1
Power cord and clamp
Heat sink DSE H-3400
Two 2 pole 2 position 240 V Toggle switches
Two terminals
Meter 1 mA FSD scaled 0-16 V, 0-1.2 A
Knob

*If meter is not required delete RV3, RV4, R10, the meter and one switch

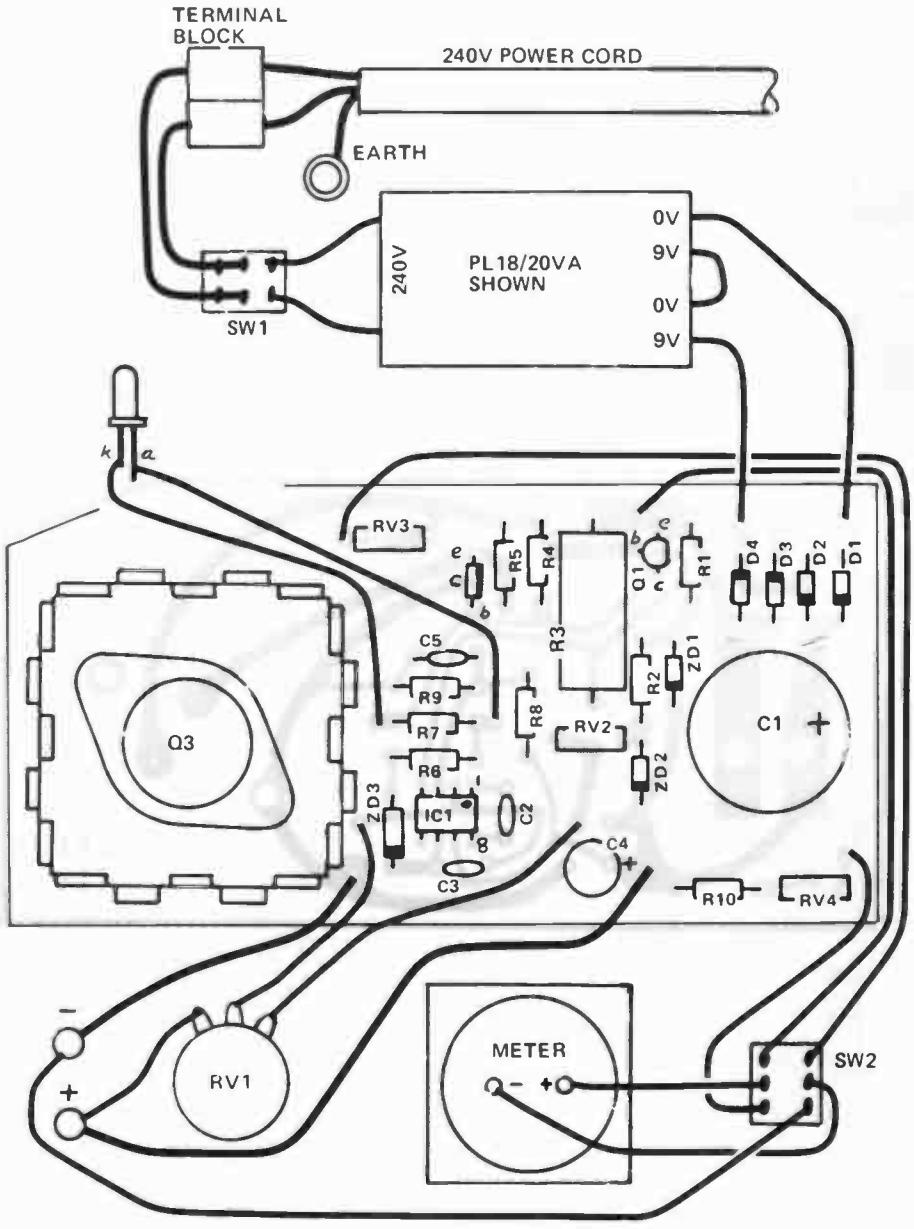


Fig 3. The component overlay and interconection diagram.

Printed circuit board and front panel layouts for this project are on page 114.

The photo on the right shows the second version of the power supply – where the voltage is set using a calibrated pot rather than a meter.

can be fitted before drilling and used as a template. Take care, however, not to scratch the panel.

Assemble the front and rear panels and wire the unit accordingly to Fig 3.

The wires to and from the power switch can pass the pc board via the chamfer on the lower left hand side. Other wires from the pc board to the front panel can be connected onto the copper side of the board.

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dc Power Supply

This new power supply has high current, high voltage capability.

SPECIFICATION - ETI 142

Output voltage	0 - 30V
Output current	0 - 15A
Regulation	20mV (0 - 15A)
Ripple and noise	10mV
Metering	
Voltage	0 - 15V, 0 - 30V
Current	0 - 1.5A, 0 - 5A, 0 - 15A
Overload indication	
Warning	if run continuously in this mode supply may shutdown.
Shutdown	if transformer gets too hot due to a continuous overload the supply will shut down until it has cooled.
Maximum output (not continuously)	24V 15A 26V 12.5A 28V 11A 30V 8A

World Radio History

THIS POWER SUPPLY was designed to extend the range of dc supplies we have published over recent years. It is capable of supplying voltages from zero to 30 volts and current up to 15 amps. The techniques used allow a high power output while retaining a small physical size.

Design Features

Once again, as with all power supply designs, there is a choice to be made as to the technique of regulation to be used. Starting from the most efficient we have:

The switched-mode power supply

With this system the mains voltage is rectified to give 340 volts dc and an inverter using an inexpensive ferrite transformer gives the low voltage required. While regulation against line and load changes can be built in, it is not suitable where the output voltage has to be variable over a large range.

Switching regulator

This utilizes a conventional transformer/rectifier but the regulation is done by switching the output at about 20 kHz with a variable markspace ratio. The output is filtered by an LC network with a diode protecting the switching transistor. This system is efficient but is fairly complex where good regulation is needed and some 20 kHz ripple appears on the output.

SCR regulator

This simply uses two SCRs in the rectifier circuit with the phase angle of their firing controlling the output voltage. This scheme has the disadvantage of having a slow response time and normally a choke input rectifier/filter is necessary.

Series regulator

This is the most common regulator in use today and has good response time, ripple rejection and regulation. Power dissipation however is high when drawing high currents at low voltages on a variable output unit. It is usually used up to about 100 watts with other systems used above this.

Shunt regulator

This is normally limited to about 10 watts, for, while the performance is very good, the dissipation is more than the maximum output on no load.

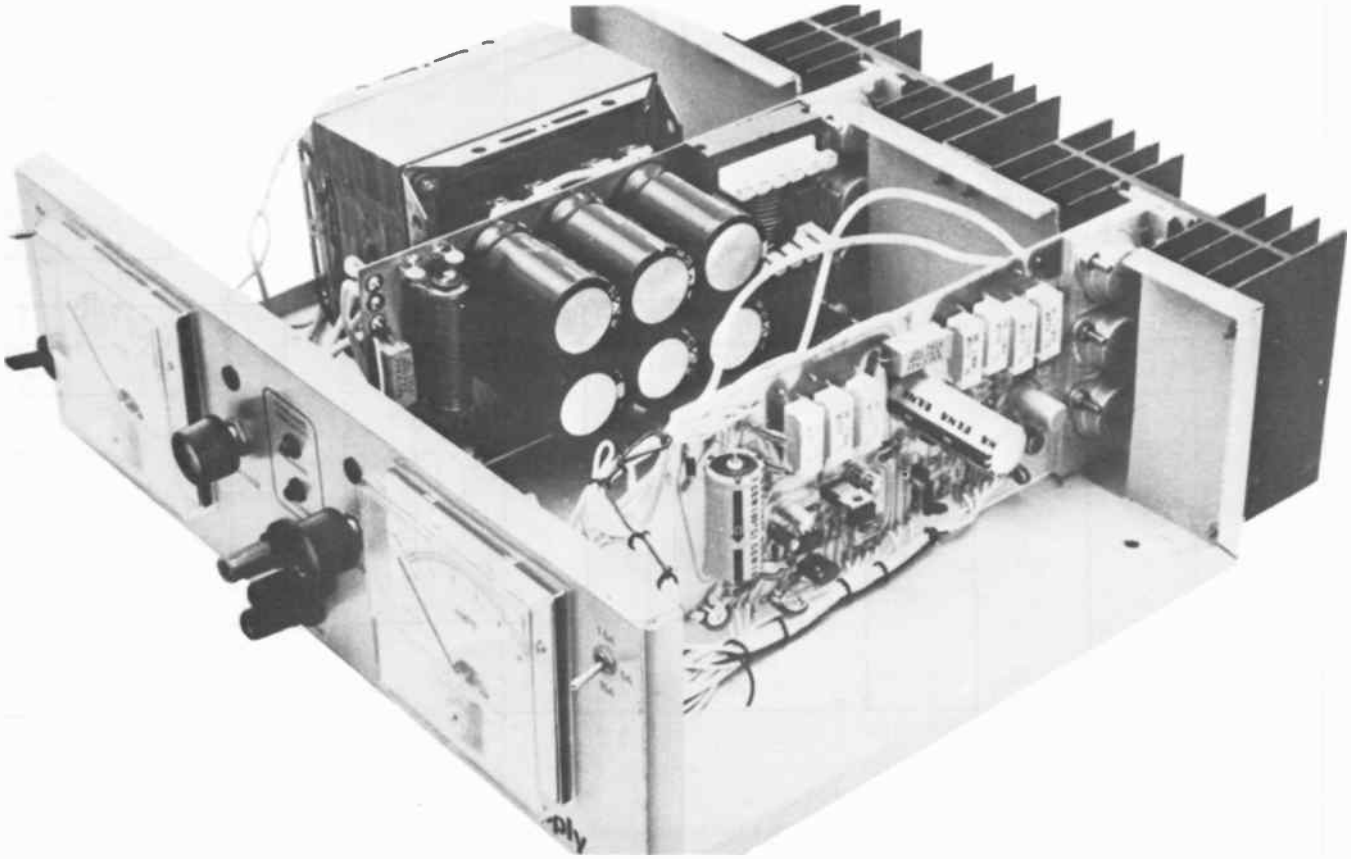
When we originally built the unit we intended using an SCR pre-regulator followed by a series final regulator. The SCR pre-regulator was to give an output about 5V above the required output. To reduce cost and size we chose not to use a choke input filter. While we could regulate the output the transformer became hot with low (dc) output voltage. The reason soon became apparent when some maths was done.

At low voltages a very short SCR conduction time is used and as the current out times time must equal current in times time for the main capacitor the input current can be 5 or 10 times the dc load current. As heating of the transformer is due to the current in the windings and not the thru-power it got hot.

We then changed to a switching pre-regulator with a series final regulator. With this design the transformer output is rectified and filtered before being regulated. This system allows higher load currents to be taken at lower output voltages without the necessity of a range switch.

Problems arising from the use of a switching regulator are mainly due to the high current and fast voltage transients generating radio frequency interference (RFI) and voltage transients in the output. The RFI problem was solved mainly by the use of an earthed shield on one side of the pc board and the addition of input and output filters.

Initially we intended to vary the mark-space ratio to compensate for the 100 Hz ripple making it easier on the series regulator. However the prototype exhibited a tendency to oscillate at around 1 kHz due to the delays in the output filter; either a more complicated control circuit would be needed or we should let the series regulator get rid of the 50 Hz ripple. We chose the second approach.



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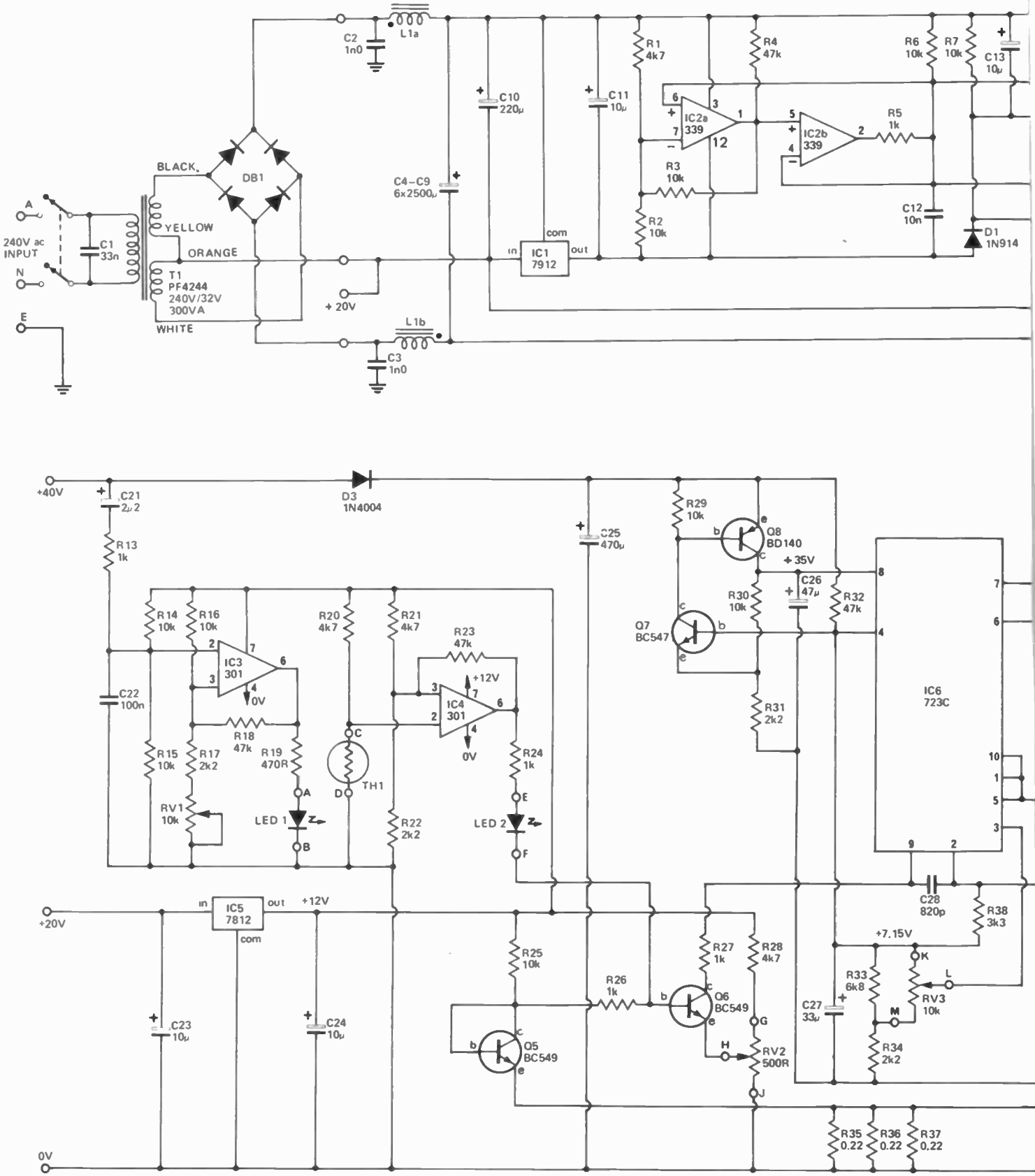

Fig. 1. The circuit diagram of the switching pre-regulator (top) and the series regulator (lower).

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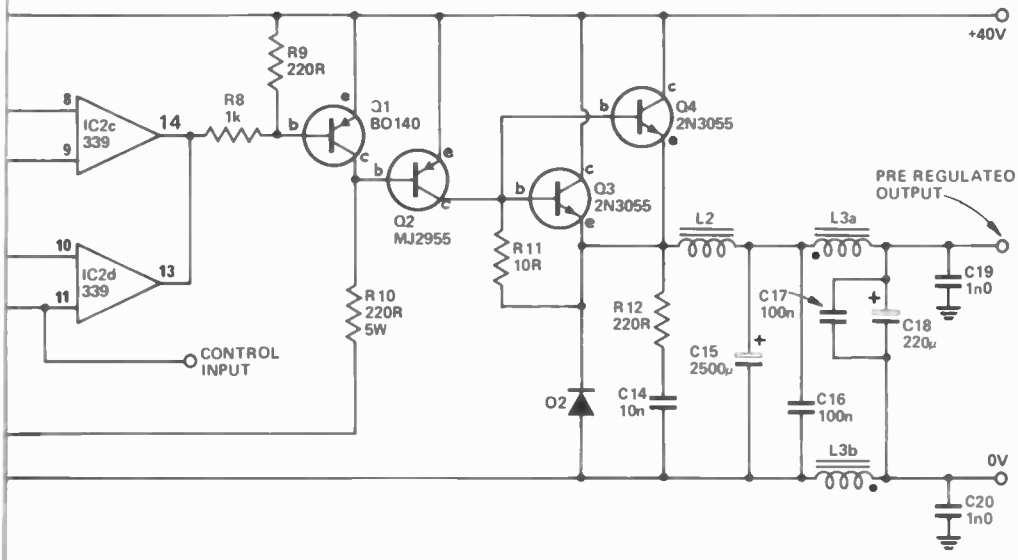

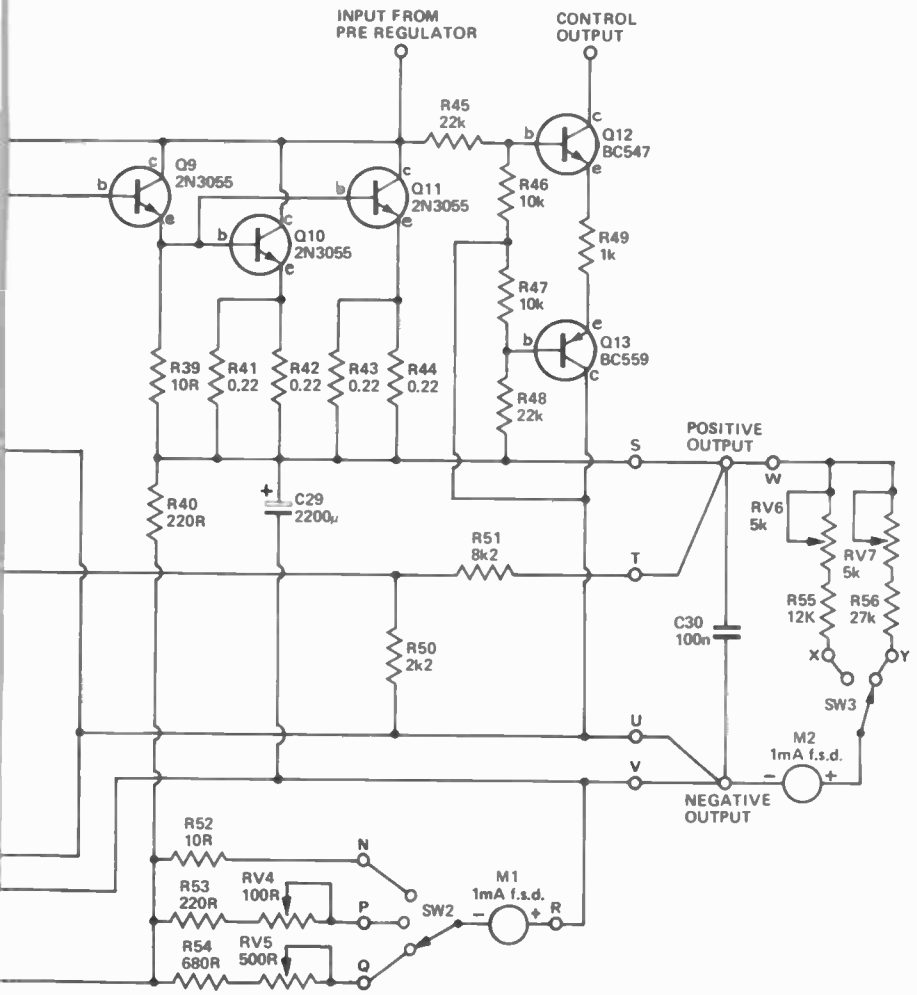

Owing to space limitations, it is not possible for us to print the printed circuit patterns or the metalwork drawings. However, these are available directly from ETI on receipt of a large, stamped self-addressed envelope. Send it to: PSU Drawings, Electronics Today, 15 Boundary Street, Rushcutters Bay, NSW 2011.

Construction

The two chokes on the ferrite rods can be wound according to table 1, and the appropriate diagram. Note that the two layers are wound in *opposite* directions and that the start and finish of each coil occurs on diagonal corners. After winding the first layer it is best to smear epoxy cement over it so that it will stay in place.

The main choke can now be wound with four close-wound layers of wire. Bring the start and finish out through the slots in the bobbin. Smear some epoxy over the outer layer to prevent movement and, after it has set, break the ends of the bobbin off as shown in the photograph. This is to enable the coil to be fitted through the hole in the pc board. Break the ends on the *opposite* side to the start/finish.

In the switching regulator the only emitter resistor used with the output transistors is a length of pc board track. It is necessary to ensure that the two transistors used have reasonably close base-emitter voltages. A selection can be made from the five used in the unit by joining the base and collector with a lead and passing 2 to 3 amps from collector to emitter (unless a current source is available it may be simplest to use a 12V battery with a 24-32W globe in series). The two which have the closest base-emitter voltages should be used.

Begin assembly of the switching pre-regulator board by mounting the board on the heatsink brackets with the transistors. As the current passes through the mounting screws it is recommended that 4BA or 4 mm brass screws be used. Also, tin the area where the screws contact the board. Some insulating tubing should be inserted in the holes to prevent the screws touching the sides. Mica insulation washers should be used under the transistors with silicon grease on *both* sides of each washer and also between the two brackets. Before tightening up, temporarily mount the brackets onto the heatsink to ensure that the mounting surface mates well. Tighten a couple of the screws holding the brackets onto the board remove the bracket from the heatsink, then tighten the rest of the screws on the board. As it takes the silicon grease some time to spread out it is best to re-tighten these screws again just before the unit is finally mounted on to the heatsink.

Check that the insulation washers are doing their job and solder the base and emitter leads of the transistors. The diode can also be mounted onto the heatsink using mica and insulation around the stud.

The rest of the components can now be mounted with the exception of the main choke, L2. Be careful that none

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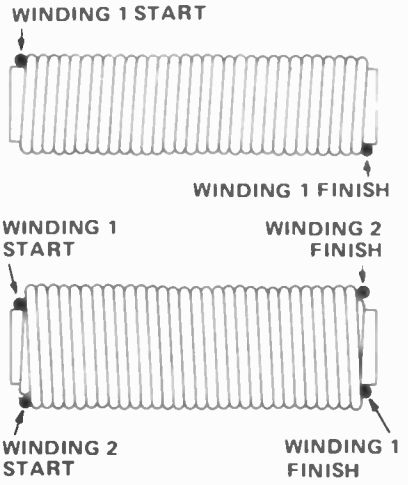


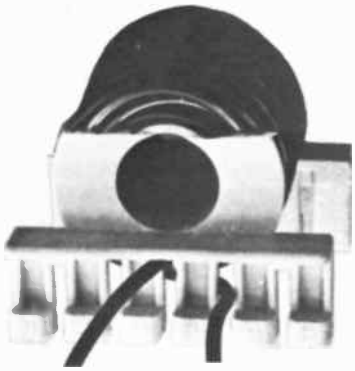
Fig. 2. L1, 3 with the first layer wound (top) and with both layers wound (lower).

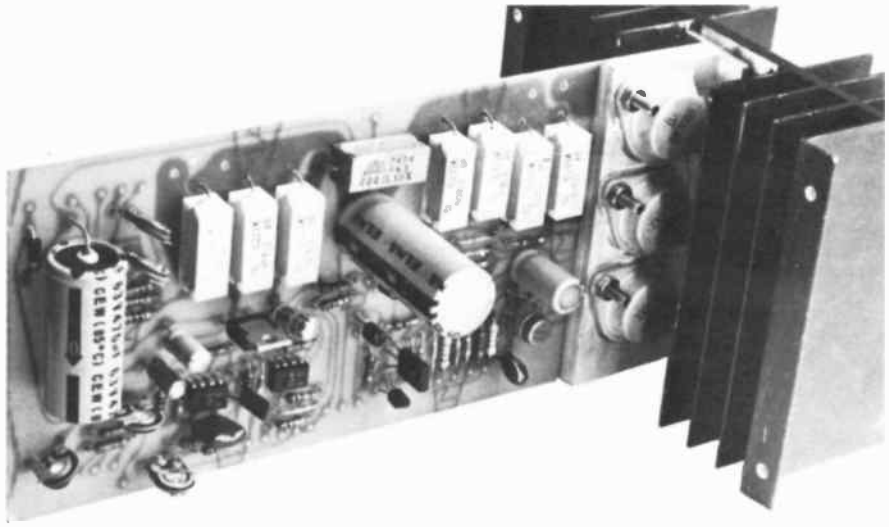
Choke Winding Data Table 1

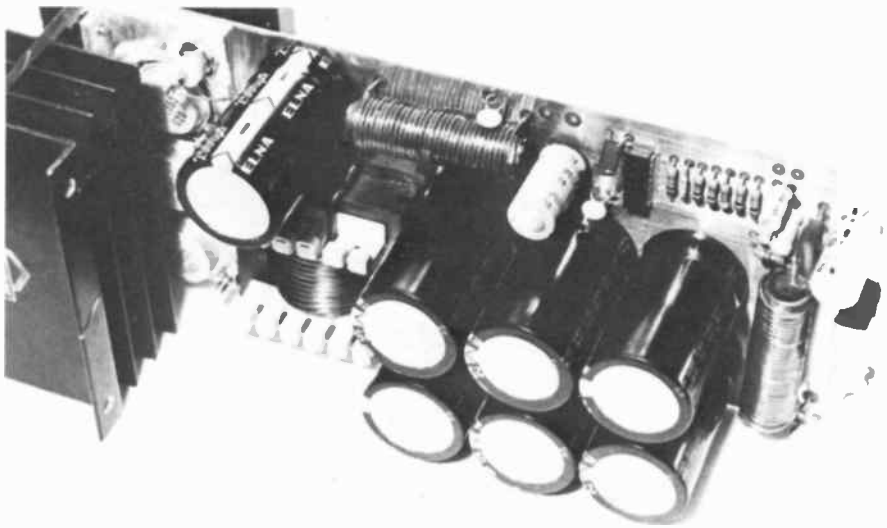
L1, L3	
Core	50mm long, 10mm dia. ferrite rod
Winding 1	single layer, close wound, 1.25mm dia. copper wire
Winding 2	single layer, close wound, 1.25mm dia. copper wire

Note that the two windings are wound in opposite directions. See diagram.

L2	
Core	Philips FX3740/4322 020 52520 (2 required)
Bobbin	Philips DT2740/DT2743
Winding	48 turns 1.6 mm copper wire
Gap	5mm







of the components touch the earth screen (with the exception of C2, 3 and C19, 20 which go to ground).

Mounting the Core

Cut two pieces of card or some other non-ferrous material, about 10 mm x 10 mm with a thickness of about 5 mm. These are glued onto the outer legs of one half of the core of L2. Several pieces can be laminated to give the required thickness if required. Slide both halves of the core into the former and bend the leads into such a position that the assembly will fit into the holes provided with no stress on the leads. Lift the coil out, clean the insulation off the leads where needed, place some epoxy on the side of the cores which contact the pc board and refit to the board. When the epoxy is set, the leads can be cut and soldered.

The start of the assembly of the series regulator board is similar to the first board with the exception that there is no power diode used. The board can be assembled according to the overlay – the only point to watch being that the 5 watt resistors should be mounted off the board by 1 or 2 mm, especially if anything but a fibreglass pcb is used (the resistors get warm!).

Start wiring by cutting 17 pieces of

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hookup wire about ½ meter long, baring one end and soldering them into the lower row of holes in the series regulator board. Add similar wires to the switching regulator board for the +40V and control input connections. To the output pads on this board, add about 200 mm of wire capable of handling 15A.

Mark the ends of all these wires with the letter on the overlay (a small square of paper held on with tape is easiest). The two boards can now be mounted onto the appropriate heatsinks using silicon grease on the contact area.

Before fitting the pc board to the chassis, mount the transformer, rectifier DB1, 3 core flex, front panel and front panel components. The pcb/heatsink assemblies can now also be added. On our prototype unit the transformer had lugs on the transformer but others will have leads. Note that the wiring that carries the power must be capable of carrying 15 amps or more.

The front panel can now be wired in accordance with fig. 3. Note that C30 is mounted directly across the output terminals on the front panel and similarly C1 is mounted on the power switch. Insulate the bare connections of the power switch with insulation tape to prevent accidental contact.

The thermistor should be soldered onto the appropriate leads (C and D), initially cutting the leads to about 5 – 6 mm long. It should then be epoxied onto the side of the coil in the power transformer. Use the 'slow dry' type of epoxy as this normally works better at elevated temperatures.

Testing and calibration

With a power supply as big as this one, initial power-up is always nerve-wracking and sometimes dramatic. If one is available use a variac to bring up the voltage. If a variac is not available set both the voltage and current limit adjustments to about mid position and switch on.

The voltmeter should now read about 15 volts and it should be adjustable using the voltage control. Measure the voltage between the input and output of the series regulator – this should be about 6 volts. This checks the operation of the switching regulator.

Add a load to the unit to check the operation of the series regulator. If it is correct the meters can now be calibrated. For the low current range (1.5A) it is necessary to select R52 to calibrate the meter (the value is too low for a trim potentiometer).

To set the trim pot for the "warning" LED it is necessary to adjust the unit to 12V output and to load it to 10 amps. The potentiometer can now be adjusted until the led just lights.

HOW IT WORKS - ETI 142

Rectifier

The 240V AC is transformed to 32 V AC by T1 with DB1 rectifying it to give about 45V DC. On full load this voltage will fall to about 35 volts. For the purposes of this description we will refer to this as +40 volts (nominal value). The centre tap of the transformer is used to derive a centre tap DC voltage, reducing power dissipation in some of the electronics.

Switching pre-regulator

In this section, IC1 is used to generate a supply voltage 12 volts *below* the positive supply rail and this powers IC2. This IC has two functions: IC2a and IC2b form a triangular wave generator and IC2c and IC2d a comparator. The voltage on pins 8 and 10 of IC2 is the triangular waveform, varying from -3.6V to -6.3V (referred to the positive rail) with the rising part taking about 50 μs and the falling edge being about 4 μs. This gives a frequency slightly less than 20 kHz.

The comparators IC2c and d are connected in parallel simply to give additional drive capability. The output stage of the 339, for those unfamiliar with it, is simply an open-collector NPN transistor with the emitter joined to the negative supply rail. If the voltage on the control input is within 3.6V of the positive supply rail, the comparator output will be high and so Q1 will be off, Q2 on and Q3 & 4 on. Transistors Q3 and Q4 are in parallel to give additional drive and current sharing is helped by emitter resistance made up of about 60 mm of copper track on the pc board. These transistors should however be the same brand and selected to have similar base-emitter voltages.

If the control voltage is more than 6.3V from the supply rail the comparator output will be low, turning on Q1. This turns Q2, 3 and 4 off. The control voltage oscillates between -3.6V and -6.3V and so the transistors will be turned on and off at 20 kHz, the mark to space ratio being controlled by the control voltage. This effectively varies the output voltage.

The output of Q3, 4 is filtered by L2 and C15 to give a smooth DC voltage. A flyback diode, D2, is necessary and must be a fast recovery type to reduce power dissipation in the transistors. While the choke has an AC voltage across it the current is DC with an AC ripple. For this reason a substantial air gap is used to prevent the core saturating when the current rises to around 15 amps.

Series Regulator

The basis of the regulator is the familiar 723 monolithic regulator IC. The output of this IC is buffered by Q9-Q11 giving the required 15 ampere capability. Normally this IC cannot regulate to below 2V because of the limitations of the comparator. To get around this problem resistor R38 provides some bias current such that when the output voltage is zero the comparator input (pin 2) is above the 2V lower limit. Similarly the potentiometer which controls the output voltage varies not from zero, but from about 2 volts up to the reference voltage from the IC (pin 4) at 7.15 volts.

For those not familiar with the IC, it compares the voltage at pins 2 (inverting) and pin 3 (non-inverting) and adjusts the output on pin 6 to compensate. While this IC can vary the output voltage to within 3 volts of the positive supply rail, it does have a maximum supply of 40V. With this circuit, on no load the supply rises to about 45 volts, too high for the IC. To overcome this we have used a two transistor regulator (Q7, 8) using the reference voltage in the 723 IC to give about 35V on pin 8 of the 723. On full load the regulator ceases to operate as the ripple on the supply rail drops below the 35 volts required. An additional isolation diode and storage capacitor are used to maintain as high a voltage as possible.

Control of the preregulator is done by Q12 and Q13. The voltage from the preregulator and the actual regulated output voltage are both divided by three; if the differential voltage is greater than about 3.6 volts Q12 and Q13 will start to conduct. The collector of Q12 goes to the control input of the preregulator card to vary the voltage from the preregulator. The action of these transistors is to maintain about 5-6V differential between the desired output voltage and the preregulator output.

Current limiting is done by measuring the voltage across R35-37 using Q6. A second transistor Q5 is used to compensate for the 0.5-0.6 volt base-emitter voltage of Q6 and also to compensate for any temperature variations, in the base-emitter voltage.

If the current exceeds the preset value Q6 will start to conduct pulling current out of pin 9 of the 723 IC. This will reduce the output voltage to prevent the current rising above the preset limit.

Current measurement is done simply by measuring the voltage across R35-37. Three ranges are provided. Voltage measurement is done directly across the output terminals with two ranges provided.

The supply is capable of delivering high currents at high voltages for short periods; overload indication is provided by IC3 and IC4. The first of these, IC3, measures the amplitude of the ripple voltage on the main filter capacitors. This effectively gives an indication of the current being drawn from the transformer. When it exceeds a preset level, IC3 changes state, lighting up LED1.

The second indication is given by IC4 which measures the resistance at a thermistor glued onto the transformer. If the resistance drops below about 2.2k ohms the output of IC4 will go high, lighting LED2 and also shutting down the output by overriding the current limiting.

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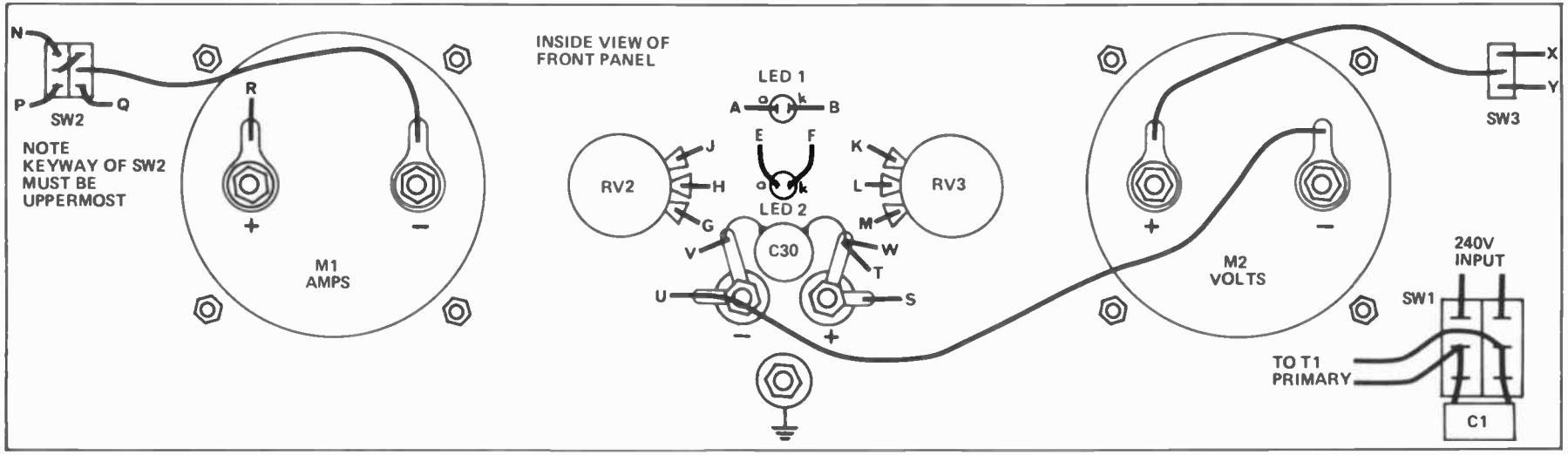

Fig. 3. The front panel wiring diagram.

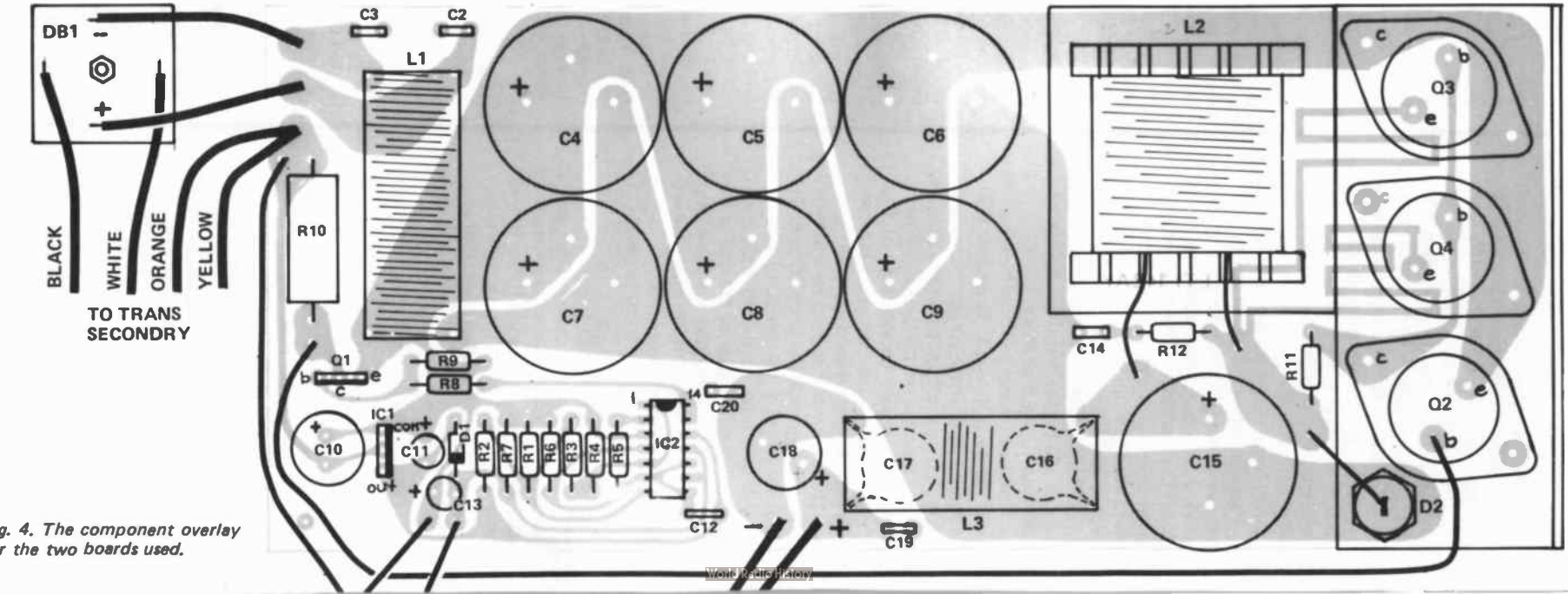

Fig. 4. The component overlay for the two boards used.

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PARTS LIST – ETI 142

Resistors all ½W, 5% unless stated

R1 . . . . . 4k7
R2,3 . . . . . 10k
R4 . . . . . 47k
R5 . . . . . 1k
R6,7 . . . . . 10k
R8 . . . . . 1k
R9 . . . . . 220R
R10. . . . . 220R, 5W
R11. . . . . 10R
R12. . . . . 220R
R13. . . . . 1k
R14–R16 . . . 10k
R17. . . . . 2k2
R18. . . . . 47k
R19. . . . . 470R
R20,21. . . . . 4k7
R22. . . . . 2k2
R23. . . . . 47k
R24. . . . . 1k
R25. . . . . 10k
R26,27. . . . . 1k
R28. . . . . 4k7
R29,30. . . . . 10k
R31. . . . . 2k2
R32. . . . . 47k
R33. . . . . 6k8
R34. . . . . 2k2
R35–R37 . . . 0.22Ω, 5W
R38. . . . . 3k3
R39. . . . . 10R
R40. . . . . 220R, 5W
R41–R44 . . . 0.22Ω, 5W
R45. . . . . 22k
R46,47. . . . . 10k
R48. . . . . 22k
R49. . . . . 1k
R50. . . . . 2k2
R51. . . . . 8k2
R52. . . . . 10R
R53. . . . . 220R
R54. . . . . 680R
R55. . . . . 12k
R56. . . . . 27k

Thermistor

TH1. . . . . Philips 2322 640 90004

Potentiometers

RV1 . . . . . 10k trim
RV2 . . . . . 500R lin rotary
RV3 . . . . . 10k lin rotary
RV4 . . . . . 100R trim
RV5 . . . . . 500R trim
RV6,7 . . . . . 5k trim

Capacitors

C1. . . . . 33n 250Vac
C2,3 . . . . . 1n0 disc ceramics
C4–C9 . . . . . 2500µ 63V RP electro
C10. . . . . 220µ 35V RB electro
C11. . . . . 10µ 35V RB electro
C12. . . . . 10n polyester
C13. . . . . 10µ 35V RB electro
C14. . . . . 10n polyester
C15. . . . . 2500µ 63V RP electro
C16,17 . . . . . 100n disc ceramics
C18. . . . . 220µ 50V RB electro
C19,20 . . . . . 1n0 disc ceramics
C21. . . . . 2µ2 63V RB electro
C22. . . . . 100n polyester
C23,24 . . . . . 10µ 35V RB electro
C25. . . . . 470µ 63V RT electro
C26. . . . . 47µ 63V RB electro
C27. . . . . 33µ 16V tantalum
C28. . . . . 820p ceramic
C29. . . . . 2200µ 35V RB electro
C30. . . . . 100n disc ceramic

Inductors

L1. . . . . see table 1
L2. . . . . see table 1
L3. . . . . see table 1

Semiconductors

IC1 7912
IC2 . . . . . LM339
IC3,4 . . . . . 301A
IC5 7812
IC6 . . . . . 723C (metal pack)

Q1 . . . . . BD140
Q2 . . . . . MJ2955
Q3,4 . . . . . 2N3055
Q5,6 . . . . . BC549
Q7 . . . . . BC547
Q8 . . . . . BD140
Q9–Q11 . . . . 2N3055
Q12. . . . . BC547
Q13. . . . . BC559

D1 . . . . . 1N914
D2 . . . . . 1N3891R,BYX30-200R
D3 . . . . . 1N4004

DB1. . . . . MDA3502 or similar

LED1,2. . . . . Red LED with mounting

Miscellaneous

PCBs ETI 142A, ETI 142B
Transformer PF4244 (16+16V@300W)
Two 1mA TD86 meters scalled to fig.5
One 10A two pole power switch
One 7101 toggle switch (SPDT)
One 7211 toggle switch (SP3T)
Three terminals posts (red, black, green)
Two knobs
Two 45D4CB heatsinks
Two each, heatsink brackets
Metal box and cover
Front panel
3 core flex and plug
Cable clamp
Rubber feet etc.

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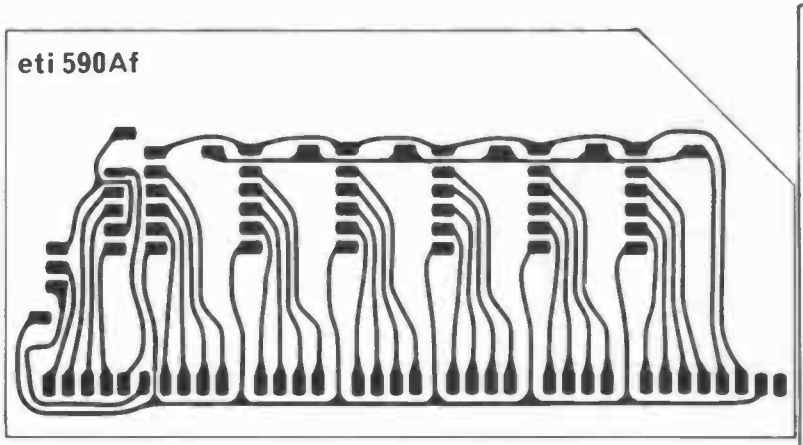

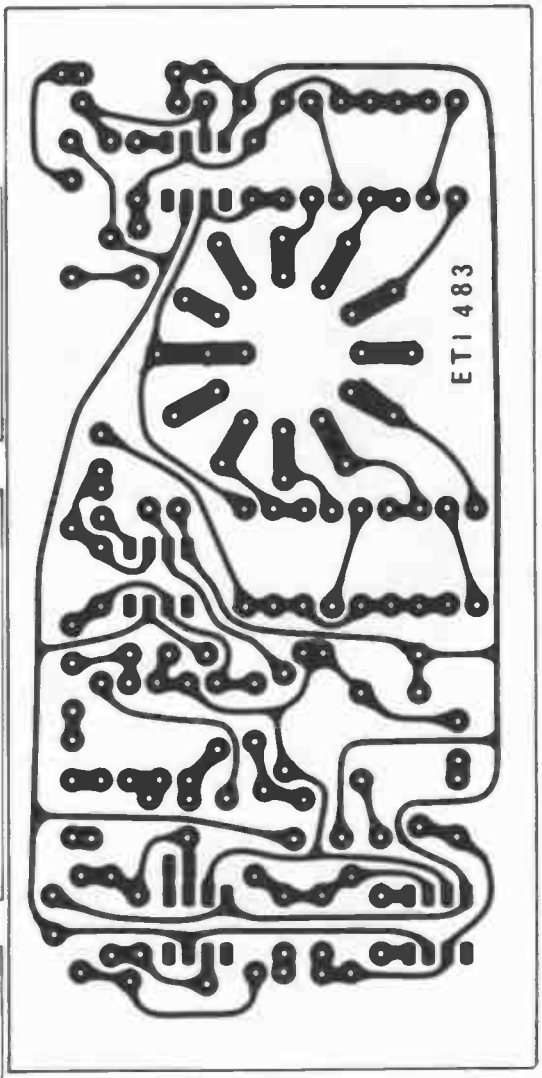

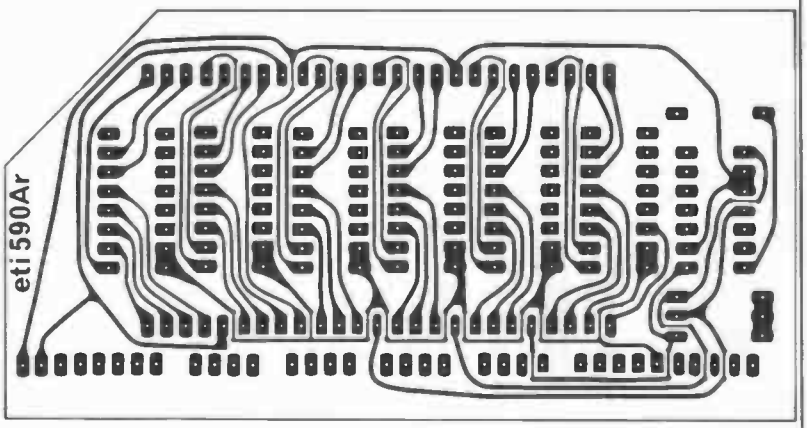

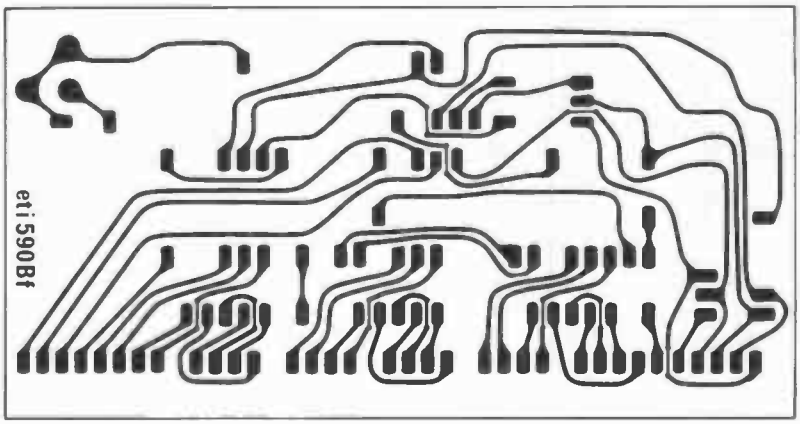

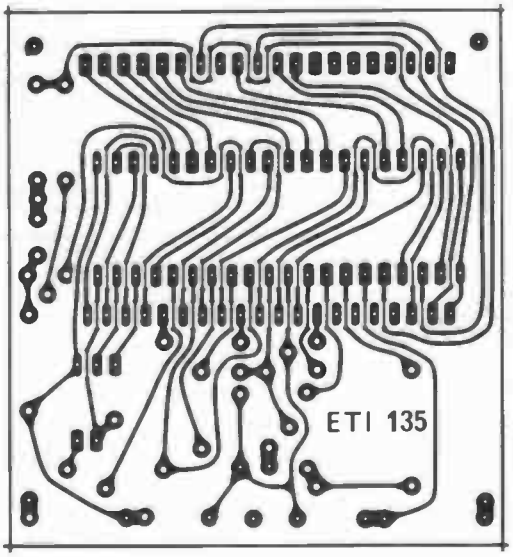

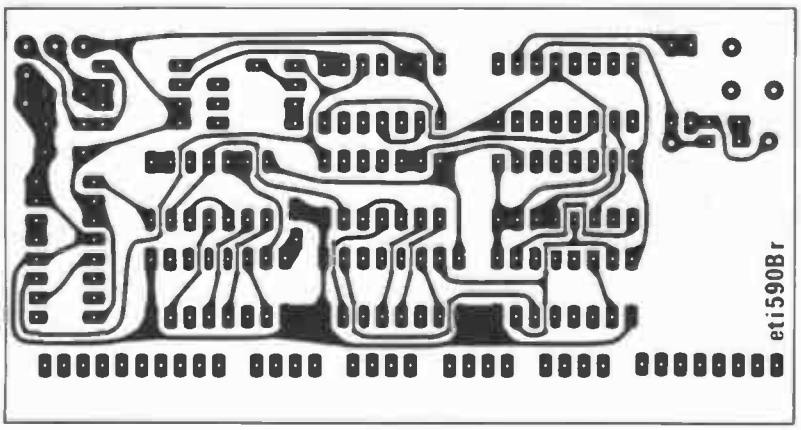

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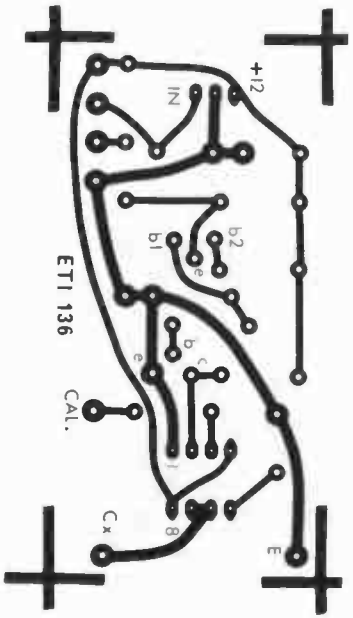

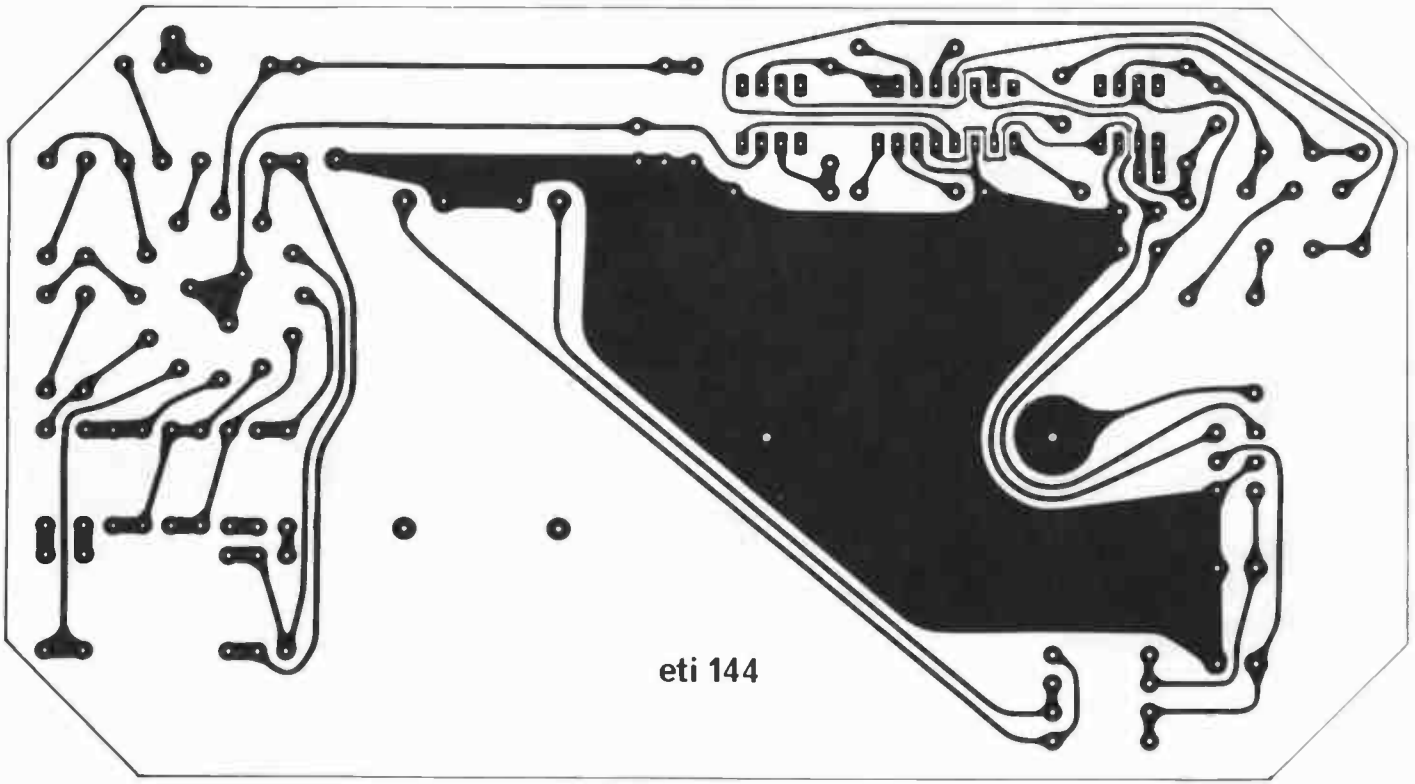

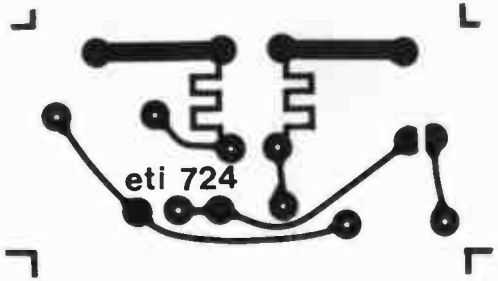

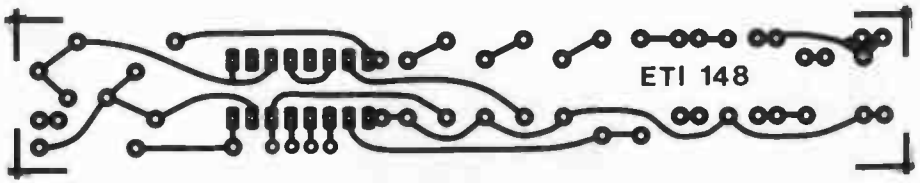

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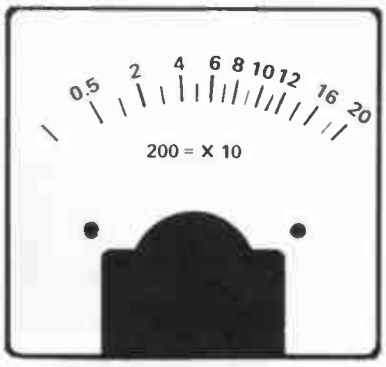

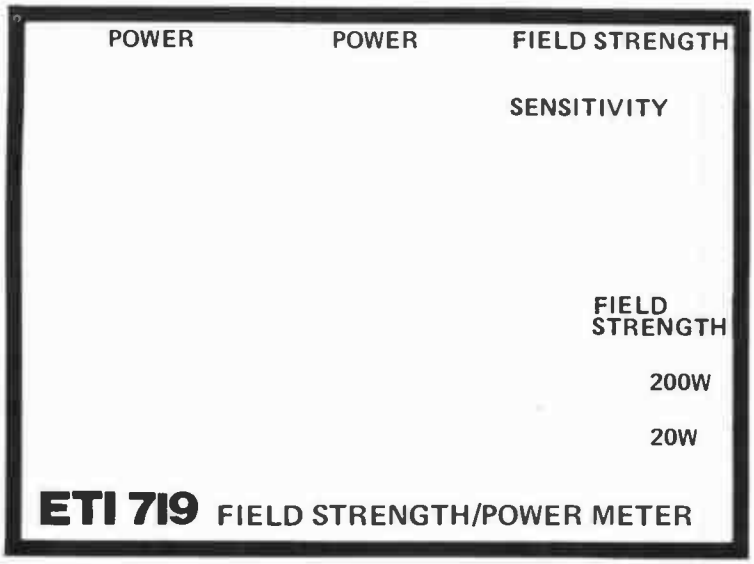

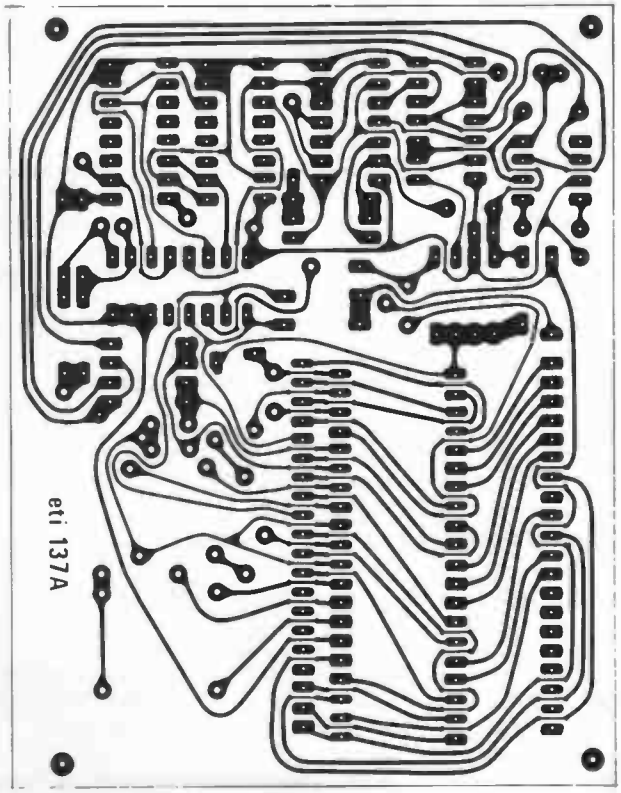

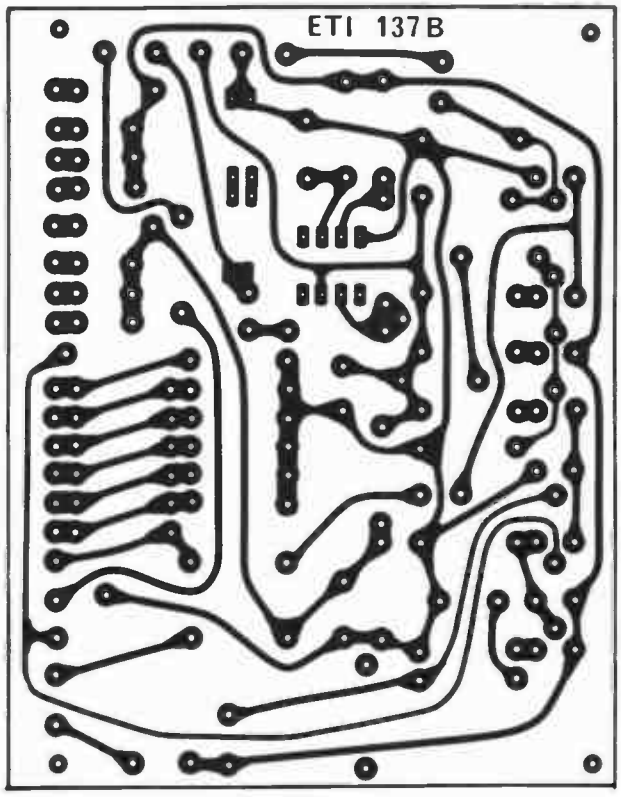

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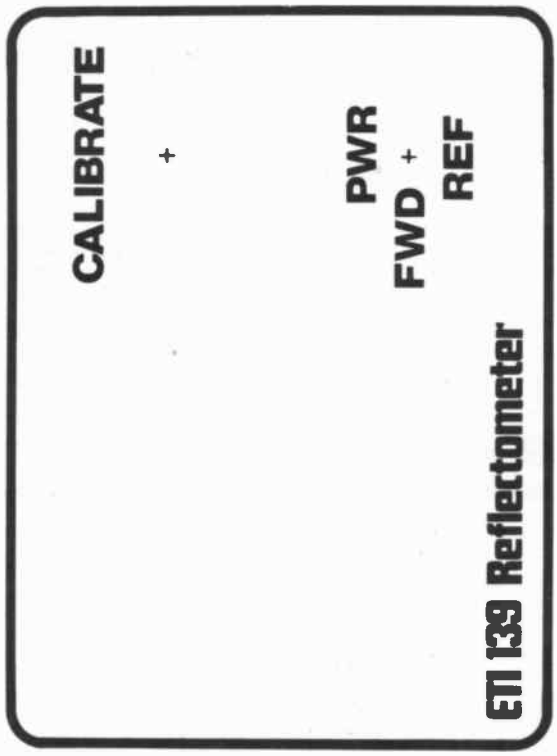

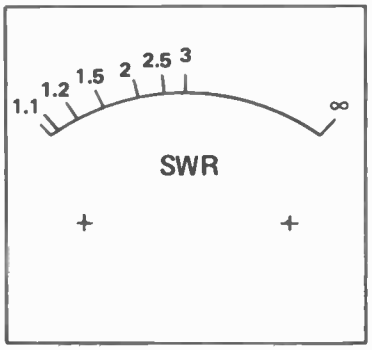

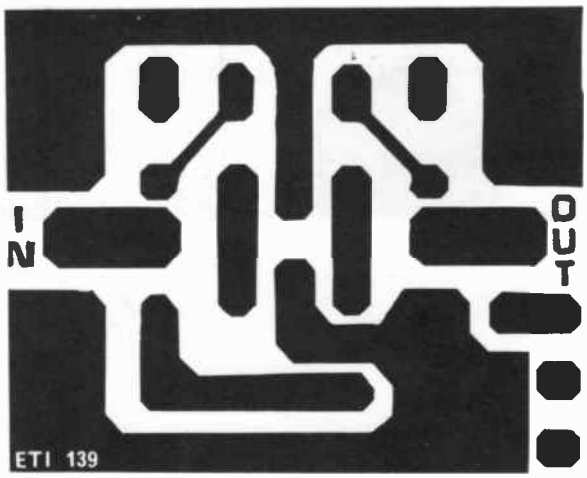

Kits & Components

THE COMPONENTS for some of the projects in this book are available as kits. Listed below are some of the companies we suggest you contact if you are seeking a kit for any particular project. Different companies specialize in different types of equipment so you may need to try several before you find the kit you want. We have also listed some suppliers for components which may be difficult to track down. Otherwise you should be able to find most of what you want by checking out the suppliers who advertise in this book and in Electronics Today International.

To our knowledge, these lists were correct when this book was printed but of course there's no guarantee that any company will continue to stock a particular component.

Kits

Applied Technology Pty Ltd,
1A Paterson Avenue, Waitara, NSW 2077.
Bill Edge Electronic Agencies,
115 Parramatta Road, Concord .
JR Components, PO Box 128, Eastwood NSW 2122.
Dick Smith Electronics Pty Ltd,
PO Box 747, Crows Nest, NSW 2065.
All Electronic Components,
118 Lonsdale Street, Melbourne 3000.
Jaycar Pty Ltd, PO Box K39,
Haymarket, NSW 2000.
Ellistronics, 289 Latrobe Street,
Melbourne, Vic 3000.
Nebula Electronics Pty Ltd,
15 Boundary Street, Rushcutters Bay,
NSW 2011.
Orbit Electronics, PO Box 7176,
Auckland, New Zealand.
Willis Trading Co Pty Ltd, 993 Hay St ,
Perth WA 6000.
Trilogy, 40 Princes Highway, Fairy Meadow, NSW 2519.

Components

The C & K Lorlin type CK 1034 or CK 1054 one pole 12 position rotary switch (project 144 - Expanded Scale RMS Voltmeter) is available from:
Radio Despatch Service, 869 George St, Sydney 2000.
George Brown, 174 Parramatta Road, Camperdown, NSW.
JES Electronic Components, 13 Melrose Street, Sandringham, Vic.
C & K Electronics, 2/6 McFarlane Street, Merrylands, NSW.
The LCD (Hamlin 3918 315) for project 590 - Digital Stopwatch comes from
Instant Component Service,
248 Wickham Road, Moorabbin, 3189.
16 Gertrude St, Arncliffe, 2205.
Suite 10, 147 Ward Street, Nth Adelaide 5006.
343 Montague Road, West End. Qld
The Intersil Evaluation Kit is available from R & D Electronics, 23 Burwood Road, Burwood, 3125.
133 Alexander Street, Crows Nest 2065.
For printed circuit boards for ETI projects, try Radio Despatch Service, 869 George Street, Sydney. NSW. 2000 or RCS Radio, 651 Forest Road, Bexley, NSW 2207.
Radio Despatch Service will also supply front panels for ETI projects.

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